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16. ABSTRACT

This report is an integrated summary of the results of the Ohio River Basin Energy Study (ORBES), a major, four year technology assessment. This study, conducted by an interdisciplinary team of researchers from eight universities in the region, investigated the potential environmental, social, economic, and public health impacts of existing and proposed concentrations of electric utility generating plants in the coal-rich basin. The study examined nine scenarios representing a range of possible patterns of energy development in the region, identified the potential impacts associated with each and examined public policy options available for dealing with these impacts. Types of impacts examined include air quality, water quality and availability, land use, ecological, health, and economic effects. Particular attention is given to local and long-range transboundary movement of air pollutants. Interjurisdictional transport of pollutants associated with acid rain is examined. The study produced over sixty supporting research documents during its four years of intensive activity. This document represents a synthesis of the results of this effort into an integrated final report.

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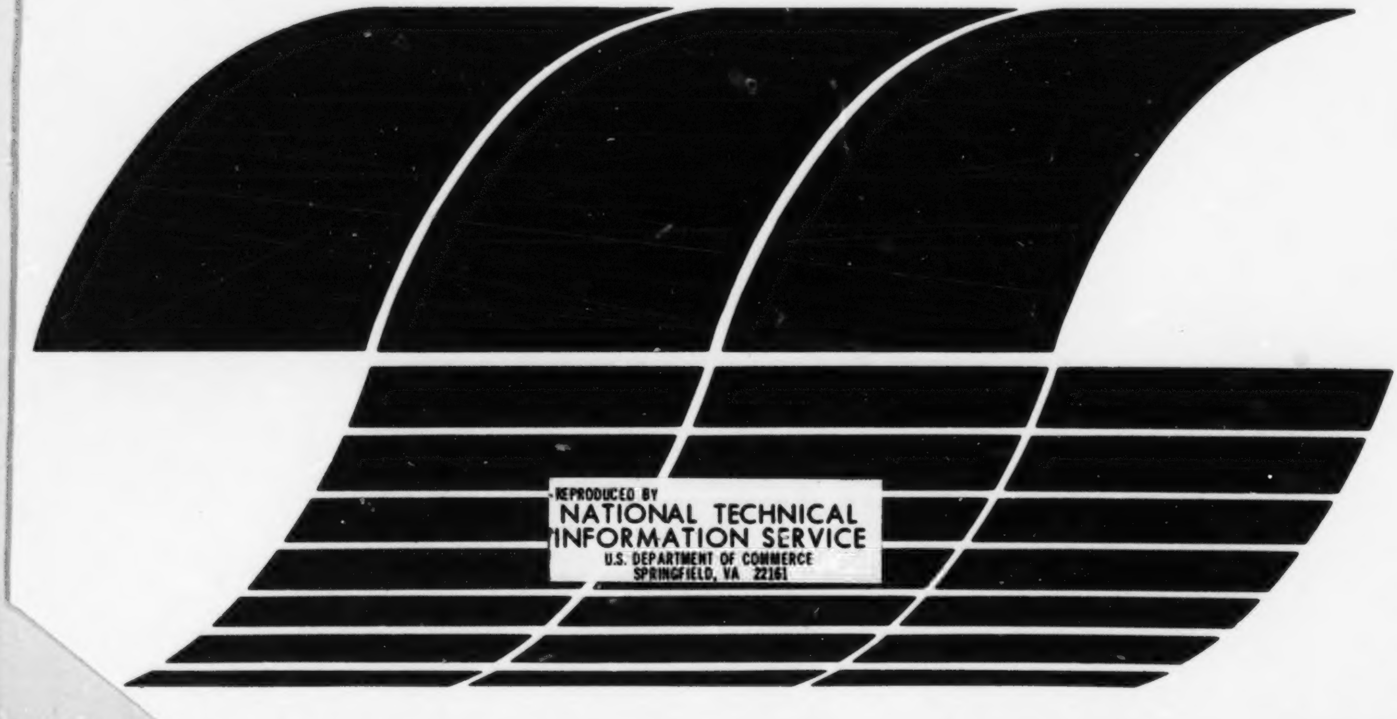

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OHIO RIVER BASIN ENERGY STUDY (ORBES): MAIN REPORT

by

The ORBES Core Team

Grant Nos. R804816, R805585, R805588, R805589,
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FOREWORD

If the development of our nation's energy resources is to be undertaken with proper consideration for the interests of all parties affected, the consequences of this development for the economy, environment, and society must be identified and understood. In its role as coordinator of the Federal Interagency Energy/Environment Research and Development Program, the U.S. Environmental Protection Agency is responsible for programs that range from the analyses of health and environmental effects of energy development to the development of environmental control technologies. A component of this interagency effort is the Strategy Research Program, (formerly known as the Integrated Assessment Program).

The Strategy Research Program was initiated in order to provide comprehensive evaluations of energy development alternatives and to identify those that are environmentally acceptable. In carrying out this responsibility, the program attempts to achieve several objectives. First, the program ties together results of scientific and engineering research programs and presents these results in a format that is useful to decision makers in dealing with policy and regulatory strategy issues. This includes feedback to the research programs concerning information needed for policy analysis but not being generated by these programs. In addition, Strategy Research combines with technical research results the socioeconomic, institutional, and policy analysis methods necessary to identify a full range of energy/environmental policy options and to evaluate their probable implications. Finally, the program attempts to identify and evaluate second and higher order impacts of development, including synergistic and cumulative effects of combinations of facilities or technologies.

The program produces results that inform the potential decision makers and interested parties of the possible consequences of alternative technologies and policies and the uncertainties inherent in projecting these consequences. The program has utilized technology assessment and other related policy analysis methods in carrying out its research. Two major projects have applied these methods to energy development in specific regions of concern. The first analyzed potential energy/environmental concerns in eight western energy resource states. The study of the Ohio River Basin is the second such regional energy technology assessment.

In the early 1970s a group of environmentally concerned citizens voiced concerns about plans for accelerated power plant development along the Ohio River. They and other basin residents sought information on the effects that energy development could have on their environment. These effects include not only the obvious physical ones on air, land, and water quality, as well as those on public health, but also less easily measurable economic and social effects. The availability of this kind of information to policy makers and interested citizens can support knowledgeable and reasonable decisions about a region's energy and environmental future.

The Ohio River Basin Energy Study (ORBES) was mandated by the U.S. Congress in response to the concerns expressed by citizens living within the basin. In the spirit of its origin, ORBES carried out the congressional directive both with the maximum degree of independence by the university researchers chosen to conduct the study and with strenuous efforts made to communicate with affected citizens throughout the research phase of the program. A major objective of this continuing communication effort was to ensure that the researchers considered those issues of greatest importance to the interested parties.

The first phase of the study (1976-1977) identified relevant energy use and environmental management alternatives and articulated a range of emerging policy issues. In the second phase (1977-1980), these issues were refined, and in-depth analyses were conducted in a number of areas.

Refinements in policy issues were made not only as a result of interim research findings and the input of the public, but also because of changing conditions nationally and within the six-state ORBES study region over the last half decade. For example, since the study began, the rate of growth in the regional demand for electricity has continued the dramatic decline begun earlier in the decade. In response to this decrease in demand many fewer power plants will be built over the next decade than previously planned. While at the beginning of the study new plants were governed by strict EPA emission standards, substantially less stringent standards apply to existing plants. Even more stringent emission requirements have been in force for those power plant units on which construction was initiated after August 1978. As a result, it is now thought that facilities currently in operation will produce the greatest effects on regional air quality throughout the remainder of this century.

The decline in the electricity demand growth rate occurred because of a number of factors that were not well appreciated at the initiation of ORBES. Among these factors were a substantial rise in electricity prices and changing demographic and economic conditions. Other factors concern the energy supply situation. For example, national efforts to begin deregulation of natural gas, a fuel that competes with electricity for many end uses, has dramatically increased the rate at which new natural gas supplies are being discovered. This fuel may become even more abundant in the Middle West if a pipeline is constructed to bring new Alaskan and Canadian supplies to U.S. markets.

Institutional awareness of and accountability for environmental issues of a regional nature have evolved rapidly since the ORBES effort began. Regional organizations such as the Ohio River Valley Water Sanitation Commission (ORSANCO) and the Ohio River Basin Commission (ORBC) increasingly are studying regional and interregional approaches, crossing many state lines, to the solution of environmental problems. Moreover, the administrators of the three EPA regional offices with jurisdiction over the ORBES states have established a task force to coordinate their pollution control efforts. Not only have government agencies on all levels become increasingly aware of regional problems, but so also have many citizens and representatives of various interests in the area begun to recognize and respond to the regional components of unresolved environmental issues, as they already do to local components of these issues.

Since its beginning in 1976, ORBES may have contributed substantially to some of these rapid changes in the study region, although claims of cause and effect seldom can be proven. The project's open research process was an experiment in communications, carried out in various ways, including a newsletter reaching almost 5000 subscribers in the study region, a series of public forums presenting research results, and written reports discussing specialized topics and overall findings. The project Advisory Committee, drawn from groups expected to be affected by regional energy development, was an especially important part of this communications process. Among the Committee members were electric utility company and coal-mining association representatives, representatives from environmental, civic, agricultural, transportation, and labor interests, designees of the governors of the six ORBES states, ORSANCO and ORBC representatives, the administrators of the three EPA regional offices, and the chief of the Ohio River Basin division of the Army Corps of Engineers.

Included in the functions of the Advisory Committee was sustained interaction with the researchers, including the opportunity to participate in internal project meetings and to review research reports in draft form. Strong EPA input also has been maintained since ORBES began, through the Advisory Committee mechanism, the project management team, and an agency work group. However, in keeping with the Congressional mandate that an independent research effort be conducted, this main report and all other project reports are entirely the product of the university researchers.

This main report summarizes the results of analyses of a range of coal-based energy development scenarios for the study region. These results include potential beneficial and adverse impacts on the environment, society, the economy, and public health. Major areas of concern include the problems associated with the long-range transport of air pollutants and the institutional difficulties in dealing with environmental problems that are regional in nature. The report also presents the results of analyses of a range of policy alternatives for dealing with adverse impacts.

The Ohio River Basin Energy Study would not have been possible without the thoughtful and sustained participation of a number of individuals, to each of whom I extend my personal appreciation. Central to the effort was the work of the 13-member interdisciplinary core team. Additional specialized inquiries were carried out by a number of support researchers. As mentioned above, the Advisory Committee played an important role throughout the project. Special recognition should be given to the project managers, Jim Stukel and Boyd Keenan, as ably assisted by Stephanie Kaylin. The insights and mature judgment that each contributed to the study left their definitive marks. Without their dedicated and unfailing efforts in coordinating this complex project, including the preparation of this main report, ORBES could not have been carried through to its successful conclusion.

Lowell Smith

Lowell Smith, Director
Program Integration and Policy Staff
Office of Research and Development

PREFACE

Release of this publication concludes the Ohio River Basin Energy Study (ORBES), a research activity undertaken by over 100 university faculty members at eight institutions in the Middle West and the area popularly known as the Ohio River valley. Grants from the U.S. Environmental Protection Agency (EPA) totaling $4.3 million funded the project.

Entitled the Ohio River Basin Energy Study (ORBES) Main Report, this document is one of a number issued since the study began in the fall of 1976. The main report is the principal element of the ORBES publication series; it represents the collective end product of a 13-member interdisciplinary faculty group known as the ORBES core team. Its members, the authors of this report, are James J. Stukel, professor of environmental engineering and mechanical engineering and director, Office of Energy Research, University of Illinois at Urbana-Champaign, and Boyd R. Keenan, professor of political science, University of Illinois at Chicago Circle, both of whom also served as co-directors of the project; and (alphabetically) Robert E. Bailey, professor of nuclear engineering and director, Program on Energy Research, Education, and Public Service, The Ohio State University; Donald A. Blome, research scientist, Institute for Mining and Mineral Research, Energy Research Laboratory, University of Kentucky; Vincent P. Cardi, professor of law, West Virginia University; Gary L. Fowler, associate professor of geography and associate director, Energy Resources Center, University of Illinois at Chicago Circle; Steven I. Gordon, assistant professor of city and regional planning, The Ohio State University; James P. Hartnett, professor of energy engineering and director, Energy Resources Center, University of Illinois at Chicago Circle; Walter P. Page, associate professor of economics, West Virginia University; Harry R. Potter, associate professor of sociology, Purdue University; J.C. Randolph, associate professor of ecology and director of environmental programs, School of Public and Environmental Affairs, Indiana University; Maurice A. Shapiro, professor of environmental health engineering, University of Pittsburgh; and Hugh T. Spencer, associate professor of environmental engineering, University of Louisville. A roster of the core team and rosters of other project participants appear in Appendix A.

On points of general policy relating to substantive research questions, the core team generally resolved conflicts by majority vote. The core team's work grew out of ORBES Phase I, which extended from the fall of 1976 through November 1977, when ORBES Phase I: Interim Findings was published. This latter publication, written by professors Stukel and Keenan, synthesized findings of the three preliminary research teams that operated independently during Phase I. As mandated by a congressional committee, the Phase I study region consisted of portions of Illinois, Indiana, Kentucky, and Ohio, and researchers were from universities in these states. However, EPA officials as well as members of Congress and their staffs agreed that in the second phase the ORBES study region should be expanded to include virtually all of West Virginia and the southwestern portion of Pennsylvania.

Core team authors generated far more specialized material for this interdisciplinary report than could be included here. Thus, they were given the opportunity to place their findings in individual core team research reports, which are referred to in this report. Additional specialized work was carried out by support research subprojects, which also are referred to in this report. These studies were commissioned by the core team. Whenever possible, support researchers were selected from the eight institutions with which the core team members themselves were associated. Such selection allowed close coordination of core team and support research efforts. In several instances, however, the necessary expertise was available only at other universities or independent research organizations.

While the main report is written primarily for the lay reader, certain of the core team and support research studies are more technical and are intended primarily for specialists. Core team review committees examined these reports for acceptability for inclusion in the ORBES series. However, their review does not represent verification of the contents.

Along with various other groups noted below, core team members were invited to comment on the final edited version of this main report. Their statements, each limited to 10 pages, comprise a separate volume. Some core team members used the opportunity to comment upon majority decisions with which they were not in total agreement.

For ORBES Phase I, EPA's Office of Research and Development, which administered the grants to ORBES participants, provided the researchers with a work plan. The core team prepared the Phase II work plan. As part of the EPA-administered Interagency Energy-Environment Research and Development Program, ORBES followed the general format of a technology assessment. A usual practice in such assessments is to develop sets of plausible, hypothetical conditions, or scenarios, in which such problems as energy development are examined.

ORBES may be unique in terms of its management framework and its openness to the public. The work of the interdisciplinary, interuniversity core team was coordinated by a management team and by a project office maintained on the University of Illinois campuses at Urbana-Champaign and at Chicago Circle. At least once a month, and sometimes more frequently, the full core team held two- and three-day working sessions that were open to the public on the various campuses and in other locations around the study region. These meetings began in the fall of 1977 and continued for two years. Moreover, during both Phase I and Phase II, open meetings on research results were held throughout the study region.

Early in Phase I, an advisory committee was appointed, consisting of representatives from government, business, labor, agriculture, the public, and other sectors. Committee membership was expanded throughout Phase II and reached a total of 43. Advisory committee members had an ongoing invitation to provide written or oral comments on core team research results. They reviewed a preliminary draft of the main report and provided considerable input throughout the study.

As with core team members themselves, each of the advisory committee members was invited to supply comments on the final version of the main report and to contribute these comments to a separate volume entitled Comments on the Ohio River Basin Energy Study. Support researchers and members of the ORBES management team also contributed to this volume.

The core team is indebted to hundreds of citizens and public officials and regrets that space limitations prevent acknowledging all of those people here. Special appreciation must be expressed to a small number of advisory committee members who attended virtually every core team meeting. The role of the media also has been important in alerting the general public to the ORBES project. Because of the complexity of the scenario approach, the media are urged to exercise care in extracting portions of the main report. That is, the results reported must be read in the context of the methodologies used to arrive at them.

The cooperation of Lowell Smith, the EPA project officer for ORBES, is gratefully acknowledged. His helpful counsel was consistent with the conditions of the individual grants that assured faculty members' independence. Neither he nor any other EPA personnel made any attempt to exert untoward influence in the preparation of this report; they did, however, make frequent efforts to sensitize the project co-directors and the core team members to the realities of government. The core team also wishes to acknowledge the assistance of the other members of the management team: James H. Phillips, of EPA Region V offices in Chicago, Illinois; Victor F. Jelen, of the EPA Industrial Environmental Research Laboratory, Cincinnati, Ohio; and David Hopkins, of EPA Region IV, Atlanta, Georgia.

The highest quality research support and staff coordination was provided by Stephanie L. Kaylin, ORBES staff associate, in the preparation of this report. Like the ORBES co-directors, she was a key member of the project from start to finish.

The usual authors' acceptance of total responsibility for errors in judgment, omissions, and misinterpretations is difficult to articulate in this instance. It has been necessary for all core team members, as co-authors, to accept on faith much specialized data from their colleagues. In instances where this faith has resulted in misinterpretations or inaccuracies deemed to be of a serious nature, project researchers have addressed the matters in their individual comments.

These procedures, as well as such unorthodox practices as inviting members of the public to participate in working research sessions, presented unusual problems for the university researchers. But we trust that certain frontiers of knowledge and public awareness have been advanced by the experiment.

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Executive Summary

1. THE ORBES PROJECT

The Ohio River Basin Energy Study (ORBES) began in the fall of 1976 in order to assess the potential environmental, social, and economic impacts of a proposed concentration of power plants in a portion of the basin. The U.S. Senate Appropriations Committee had mandated the U.S. Environmental Protection Agency (EPA) to carry out this study just after the Arab oil embargo (1973-74) in response to citizen concern. At that time several utility companies had announced plans to construct additional generating units in the Ohio River Basin.

The Ohio River region offered the electric utilities (and related industries) some of the nation's most suitable power plant sites, particularly since coalfields containing almost half of the nation's reserves by tonnage are within easy reach (see figure ES-1). Some citizens, however, questioned the necessity of adding such a large number of generating facilities, particularly near the Ohio River itself. They also pointed out that the proposed new plants would transmit much of their electricity far from the immediate area.

In an effort to identify the implications of locating future energy conversion facilities in this particular part of the Ohio River Basin, the Senate Appropriations Committee directed EPA to conduct a study "comprehensive in scope, investigating the impacts from air, water, and solid residues on the natural environment and [on the] residents of the region. The study should also take into account the availability of coal and other energy sources in the region."

2. GENERAL REGIONAL CHARACTERISTICS

The ORBES region covers 190,377 square miles in 423 counties in the states of Illinois, Indiana, Kentucky, Ohio, Pennsylvania, and West Virginia (see figure ES-2). The predominant land use in the region is agriculture, which accounts for 54 percent of regional acreage. The types of farming range from vast corn and soybean tracts in Illinois to smaller tobacco farms in Kentucky. Mixed mesophytic, northern hardwood, beech-maple, oak-hickory, and other forests cover another third of the region.

The regional river systems and aquatic life are as diverse as can be found in the United States. These regional water systems range from whitewater canoe and mountain trout streams to deep, clear lakes popular as recreational spots, major rivers both navigable and free flowing, and numerous wetlands and sloughs. These water systems support more than 250 fish species, with several of the navigable rivers containing at least 90 species and some large lakes containing over 125.

Figure ES-1
ORBES–Region Coalfields

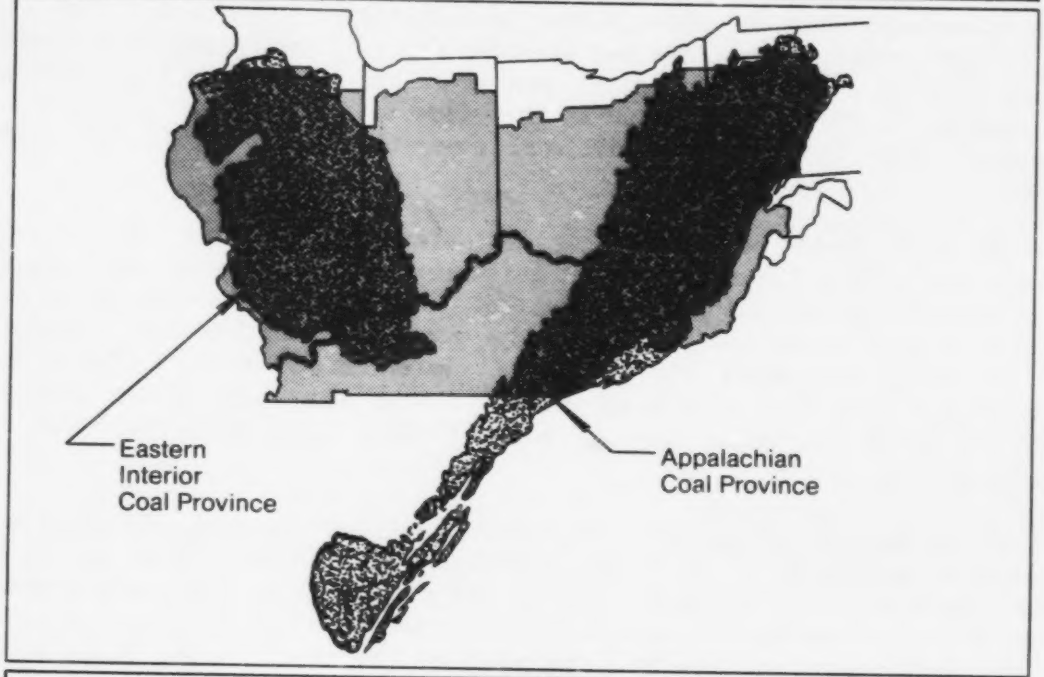
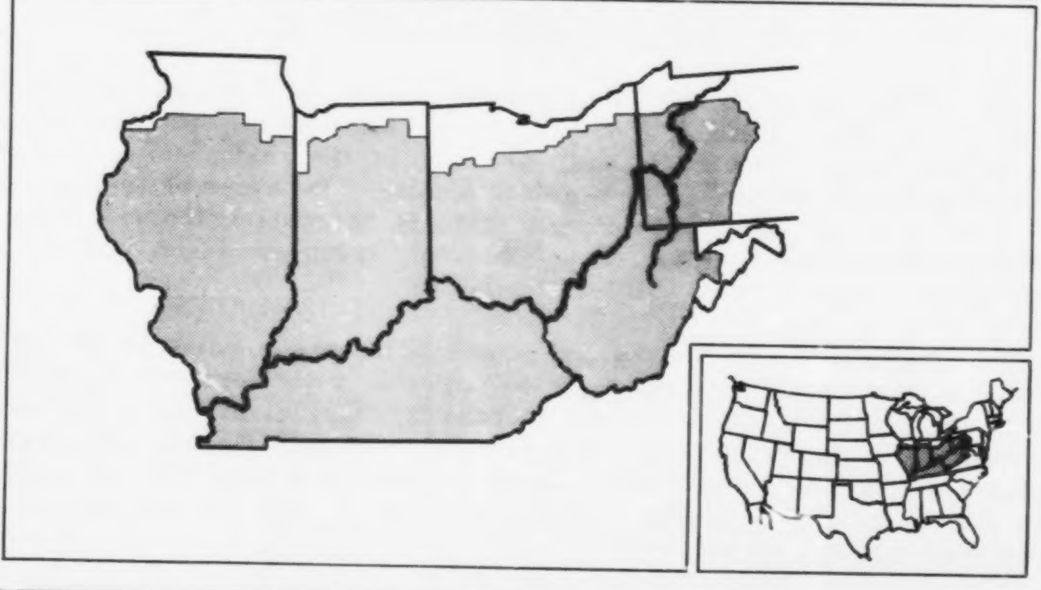

Eastern
Interior
Coal Province
Appalachian
Coal Province

Figure ES-2
Ohio River Basin Energy Study (ORBES) Region



The ORBES region contains about 11 percent of the national population and accounts for about 10 percent of the gross national product. The major economic sector in the region is manufacturing, which accounts for about 31 percent of the gross regional product, followed by trade (16 percent), government (12 percent), and finance, insurance, and real estate (11 percent). The remaining 5 sectors each accounts for less than 11 percent of the gross regional product (see figure ES-3); the coal-mining and agricultural sectors constitute 3 percent and 4 percent, respectively.

Coal is the most significant indigenous fuel in the ORBES region and accounts for two-thirds of national production. Coal also is the primary fuel used in the region. Coal use accounts for about half of the total regional fuel consumption, and the electric power industry in the region consumes about two-thirds of this coal. About 95 percent of regional electrical generating capacity is coal fired. Nonfossil fuels, in general, account for less than 1 percent of the total conventional fuel use in the region--approximately the same percentage as in the nation.

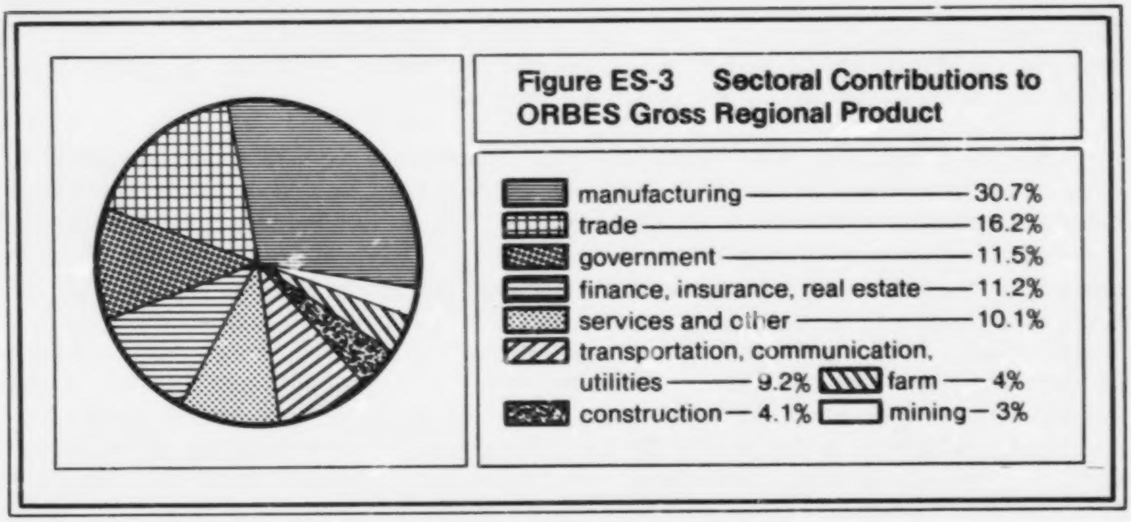


Figure ES-3 Sectoral Contributions to ORBES Gross Regional Product

3. REGIONAL AIR, WATER, AND LAND STATUS IN MID-1970s

AIR. Perhaps because of the high coal use, air quality standards for sulfur dioxide and particulates were not being met at several locations in the ORBES region during the study's base period (the mid-1970s). Several other locations were close to violation. For example, in 1977, 11 ORBES-region counties violated national ambient air quality standards (NAAQS) for sulfur dioxide, and an additional 13 counties did not have available the full prevention of significant deterioration (PSD) increment for sulfur dioxide to accommodate new sources; the ambient concentrations in these counties were at or just below the NAAQS. In the same year, 130 counties in the region violated the NAAQS for total suspended particulates (TSP), and an additional 5 counties had less than the full PSD increment available. Many of the counties that violated the TSP and sulfur dioxide NAAQS were clustered in extreme southwestern Ohio and along the Ohio-Pennsylvania-West Virginia border. However, since over 50 percent of the counties in the ORBES region are without monitoring for sulfur dioxide or TSP, the number of 1977 violations probably is underestimated.

In all probability, ORBES-region generating units contribute substantially to sulfur dioxide concentrations since they produce about 80 percent of regional sulfur dioxide emissions. In fact, in 1975, regional utility sulfur dioxide emissions constituted 52 percent of national utility sulfur dioxide emissions and 32 percent of national sulfur dioxide emissions from all sources. In contrast, during that same period, about 36 percent of the national coal-fired electrical generating capacity was located in the ORBES region.

ORBES-region utilities contributed smaller but significant shares of the 1975 regional nitrogen oxide and particulate emissions--about 47 percent of regional nitrogen oxide emissions from all sources and about 22 percent of regional particulate emissions from all sources.

However, regional data indicate that long-range transport of emissions, even over distances of several hundred kilometers, was and is an important factor in regional pollutant concentrations. At several locations throughout the region, between 30 and 50 percent of the 25 highest daily sulfur dioxide concentrations are associated with transport by extremely persistent winds. Moreover, under certain meteorological conditions, sulfur dioxide is transformed into sulfates, thereby contributing to regional sulfate concentrations. In addition, since sulfates are, by definition, the total water-soluble component in TSP, such transformation of sulfur dioxide into sulfates ultimately affects the TSP concentrations. Data from the base period confirm the importance of both sulfates and their transport in TSP concentration levels.

It is important to understand the relationship among the transport of sulfur dioxide, its transformation, and regional sulfate episodes. Sulfur dioxide concentrations of 130 micrograms per cubic meter (one-tenth of the secondary three-hour standard) in the presence of current ozone levels have been linked to vegetation damage and crop loss. Also, a growing body of evidence supports the hypothesis that the annual average exposure to sulfates--or something closely related to them--results in an increased mortality rate. In addition, sulfate episodes are correlated with acidic precipitation episodes; acidic precipitation is believed to be due primarily to the presence of sulfate and nitrate ions. Finally, sulfate episodes often are associated with the occurrence of reduced visibility over large areas.

An examination through mathematical modeling of four representative regional sulfate episodes between 1974 and 1976 reveals similarities among the episodes. In general, sulfur dioxide emissions in the lower ORBES region contributed significantly (between 50 and 90 percent) to the sulfate concentrations in the upper region. Moreover, of the sulfate concentrations in the upper region attributable to emissions in the lower region, utility sulfur dioxide emissions in the lower region contributed at least half; in at least two of the four episodes, these emissions contributed over 90 percent. (The lower ORBES region consists of the ORBES state portions of Illinois, Indiana, Kentucky, and western Ohio; the upper region, of the ORBES portions of eastern Ohio, Pennsylvania, and West Virginia.) Similar results are found when the annual sulfur dioxide and sulfate concentrations are examined.

Thus, both data and modeling confirm that long-range transport from the lower region contributes significantly to the concentration averages in the upper region and to violations of NAAQS in that region.

Finally, when the relationship between ORBES-region sulfur dioxide emissions and Canadian concentrations is examined, utility sulfur dioxide emissions from the ORBES region are shown to contribute about 50 percent of the sulfur dioxide and sulfate concentrations estimated to occur in southeastern Canada.

WATER. An analysis of the regional water quality in 1976 indicates the presence of high pollutant concentrations. These pollutants can be further concentrated by the diminished flow that occurs under 7-day-10-year low flow. In general, the minimum of the water quality standards in the ORBES states was used as a guide (since these standards vary from state to state and even from river to river). Approximately 19 of the region's 24 largest streams would have violated at least 3 of the 20 pollutant standards at some time in 1976 under 7-day-10-year low flow conditions. Moreover, if such conditions had occurred, aquatic habitat impacts could have been heavy on 14 of these 24 streams. (Heavy impacts are defined as entailing eutrophication, a concentration of heavy metals, possible stream dessication, local fish kills, and a recovery period of possibly five to seven years.)

LAND. If all energy-related land uses are considered, such land use through 1976 had affected 1.86 million acres in the ORBES region, or 1.5 percent of the regional land area. Land use for past and present surface mining of coal represents 86.9 percent of this figure (1.6 million acres); electrical generating facilities, 7.6 percent (140,700 acres); and transmission line rights-of-way, 5.5 percent (103,000 acres). In general, the reclamation of surface-mined land for permanent land use tends to be a slow process. Data are available only for a quarter of the region's 1.6 million affected acres.

These data show that this portion has been affected for 10 years and has not yet been fully reclaimed.

4. THE ISSUE AREAS OF CONCERN IN THE ORBES PROJECT

The ORBES study investigated possible impacts of an expanded generating capacity in the context of a number of issues. In the area of air quality, the study focused on the regional effects of changes in pollutant concentrations as a result of different levels of electrical generation, different control technologies, emission limitations, generating unit retirement schedules, and other factors. Examined in the context of the air quality analysis were the cost of electricity to the consumer, capital costs for pollution control devices, losses in agricultural output as the result of air pollution, and health impacts related to sulfates. In terms of land impacts, the study focused on land displacement for energy-related uses and the amount of land affected by surface mining. Another area investigated was water quality and quantity, including water consumption by electrical generating units, the effects of this consumption on pollutant concentrations (which increase as the water quantity decreases), and the effects of pollutant concentrations on aquatic habitats. The social areas chosen for analysis included labor demand for coal mining, labor demand for power plant construction and operation, and occupational death, disease, and disability from coal mining, processing, and transportation.

These topics were examined through a technology assessment approach. A variety of scenarios, all regionally based, were decided on and examined. Each scenario is thus an "as if" statement that does not predict what might happen. Rather, a scenario represents what one future might be like if assumed conditions are present in the ORBES region. Nine scenarios are compared in this report. First, those scenarios that assume an emphasis on coal as a fuel are compared. Next, those scenarios that assume a substitution of other fuels for coal or that emphasize conservation are compared with each other and with the coal-dominated scenario designated as the base case. The assumed economic and energy growth rates, as well as the assumed regional electrical generating capacity under each scenario in the year 2000, appear in table ES-1.

5. COAL-DOMINATED SCENARIOS

The five scenarios chosen for the most detailed analysis assume that coal will continue to be the dominant fuel used for regional electrical generation through the year 2000. The primary scenario of these five is the base case, the scenario to which all others are compared. Variations in base case environmental controls characterize two of the remaining four scenarios--the strict environmental control case and the noncompliance case. Variations in base case electricity demand growth account for the remaining two scenarios, the high electrical energy growth case and the electricity exports case. The latter case is so named because it also assumes that additional installed capacity in the ORBES region will transmit electricity to the northeastern United States to replace oil-fired capacity in that part of the country.

For the three scenarios that assume the same environmental standards--the base case, the high electrical energy growth case, and the electricity exports case--air and land standards are defined in terms of what currently exists as applied to present and future sources of pollution; in other words, these three scenarios reflect the full implementation of current air and land environmental policies. For water, the standards consist of current practices for the design and construction of industrial and municipal facilities. Power plant effluents, however, were assumed to be uncontrolled. The strict environmental control case, on the other hand, calls for more stringent environmental regulations. In the case of air, strict controls mean that the generally stringent pollutant emission standards for urban areas--which are set by current (as of September 1978) state implementation plans (SIPs)--would be applied throughout a state. For water, power plant effluent levels were assumed to be about 5 percent of base case levels. Strict environmental controls on land reclamation call for interim and permanent performance standards under the Surface Mining Control and Reclamation Act of 1977, but with strengthening of site-specific applications. Special interim and permanent standards are applied to steep-slope mining, mountaintop removal, the mining of prime farmland, and the surface effects of underground mining. Under the noncompliance case, it is assumed that emission limits in state implementation plans will not be met, but that the water and land environmental policies will be the same as under the base case.

Three of the five coal-dominated scenarios assume the same electricity demand growth rate: the base case, the strict environmental control case, and the noncompliance case assume an average annual rate of 3.13 percent through the year 2000. The electricity exports case, however, assumes an electricity demand growth rate of 3.2 percent, and the high electrical energy growth case assumes a rate of 3.9 percent. The high rate of electricity demand growth under the latter scenario is that suggested in recent estimates made by the National Electric Reliability Council (NERC).

The coal-dominated scenarios are further defined by a variety of energy and fuel use characteristics; growth rates for various sectors under each scenario appear in table ES-1. Also given in table ES-1 is the regional installed capacity that is projected to occur by 2000 under each scenario because of the electricity demand growth rates.

The same population, fertility, and economic growth rates were assumed for all five coal-dominated scenarios. Similarly, all scenarios assume that the coal to supply regional generating units will come from Bureau of Mines

Table ES-1
Growth Rates and Installed Capacity, ORBES Region, Annual Averages (1974–2000), by Scenario

Scenario	Economic Growth	Electricity Growth	Coal Growth	Natural Gas Growth	Refined Petroleum Growth	Energy Growth	Installed Capacity Year 2000 (MWe)
Base Case	2.47%	3.13%	2.40%	–0.40%	0.37%	1.49%	153,245
Strict Environmental Controls	2.47%	3.13%	2.47%	–0.40%	0.37%	1.53%	153,245
Noncompliance with State Implementation Plans	2.47%	3.13%	2.40%	–0.40%	0.37%	1.53%	153,245
High Electrical Energy Growth	2.47%	3.90%	N/A	–0.40%	0.37%	N/A	178,372
Exports of Electricity	2.47%	3.20%	2.77%	–0.39%	0.43%	1.73%	173,395
Natural Gas Substitution	2.47%	2.00%	0.74%	3.55%	0.51%	1.61%	113,595
Nuclear Fuel Substitution	2.47%	3.11%	1.52%	–0.40%	0.37%	1.50%	145,295
Alternative Fuel Substitution	2.47%	2.69%	1.73%	–1.20%	0.15%	0.95%	134,395
Conservation Emphasis	2.47%	0.90%	0.20%	–0.31%	–0.54%	0.10%	104,495

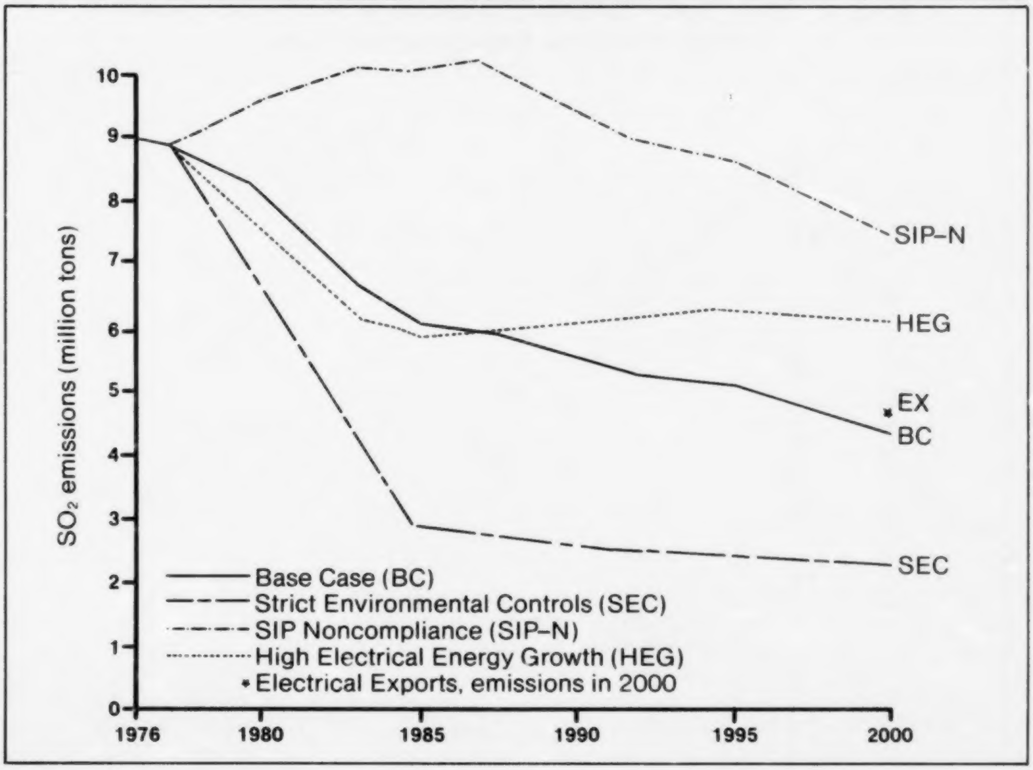
(BOM) districts in the six ORBES states (districts 1 through 4 and 6 through 11). All scenarios also assume that the regional generating units announced by the utility companies as of December 31, 1976, including both coal-fired and nuclear facilities, will be built as planned and that these facilities will come on-line on the dates announced by the utilities. Finally, all scenarios assume that sulfur dioxide emissions will be controlled through the use of flue gas desulfurization systems ("scrubbers") or the use of of local, blended low- and high-sulfur coals.

6. COMPARISON OF COAL-DOMINATED SCENARIOS

6.1 Emissions, Concentrations, and Air-Quality-Related Impacts

For all of the coal-dominated scenarios, utility emissions are the most important regional factor since their magnitude and their distribution consistently correlate with ambient air concentrations and, thus, with crop losses and mortality related to air quality. Under all coal-dominated scenarios, utility sulfur dioxide emissions would decrease by the year 2000 from their 1976 levels. However, the rate of decrease and the actual totals in 2000 would vary among the scenarios (see figure ES-4). Because of the scenario assumptions that produced the differences charted in figure ES-4, several observations can be made about possible strategies to reduce sulfur

Figure ES-4
Electric Utility Sulfur Dioxide Emissions in the ORBES Region, Coal-Dominated Scenarios

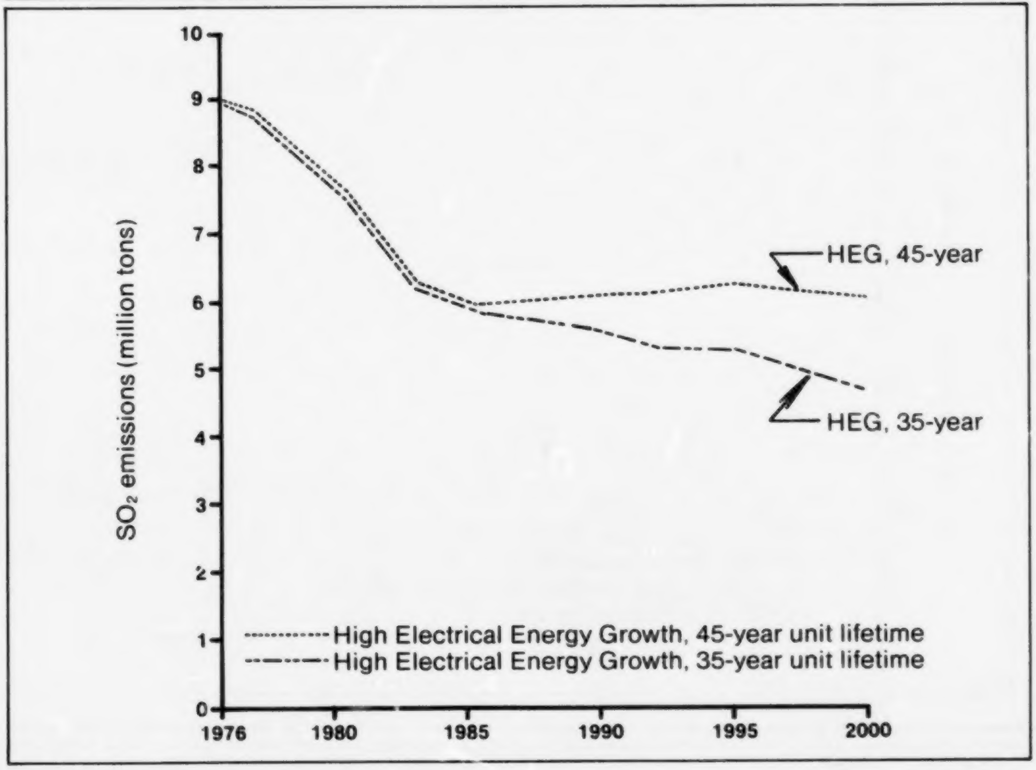


dioxide emissions at the individual plant level from their high 1976 levels. A discussion of mitigation strategies in an organizational context appears later in this summary.

SULFUR DIOXIDE

SIP Compliance. First, the base (compliance) case, the high electrical energy growth case, and the noncompliance case demonstrate how sensitive regional sulfur dioxide emissions are to compliance with and enforcement of SIP standards. Both the base case and the high growth case assume that complete SIP compliance will occur by 1985. As a result, under both scenarios, sulfur dioxide emissions are reduced continuously and dramatically between 1976 and 1985, and at about the same rate (see figure ES-5). The noncompliance scenario, however, assumes that there would be no utility compliance schedule; the SIP units would continue burning historical coals and using emission controls as in 1976. Thus, under this latter case, sulfur dioxide emissions

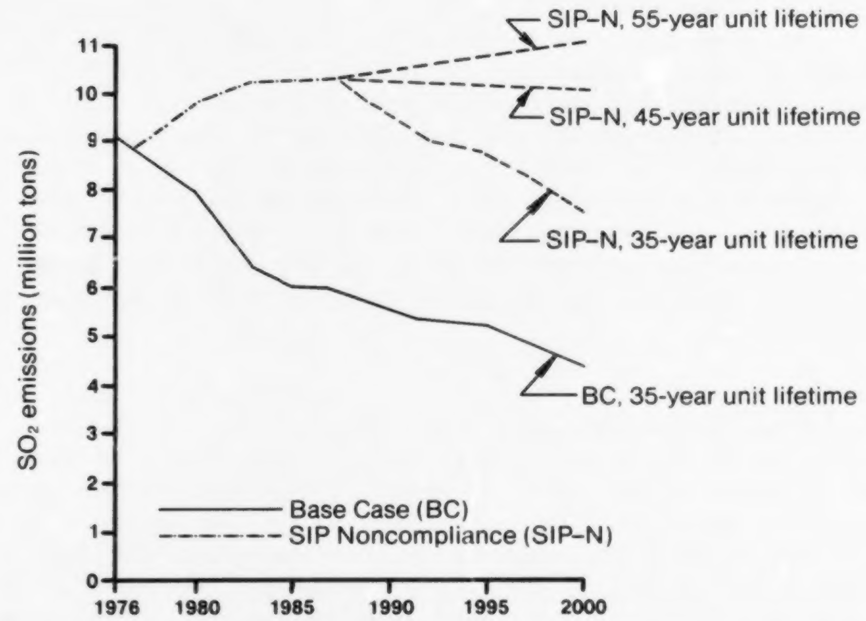
Figure ES-5
Electric Utility Sulfur Dioxide Emissions in the ORBES Region, High Electrical Energy Growth Case



actually would increase between 1976 and 1985, ensuring that the base period air quality problems would continue and perhaps get worse (see figure ES-6). Since nearly the same electrical generation is assumed in all three of these scenarios in 1985, the immediate benefits of SIP compliance are clear: total utility sulfur dioxide emissions could be reduced by one-third by 1985.

Plant Retirements. Utility sulfur dioxide emission patterns between 1985 and 2000 demonstrate yet another way to control emissions of this pollutant. After 1985, the level of utility sulfur dioxide emissions under the same three scenarios depends on the retirement of SIP units and the replacement and addition of present generating capacity by units governed by revised new source performance standards (RNSPS). Both the base case and the noncompliance case assume that SIP units will be retired after 35 years; the high growth case, on the other hand, assumes 45-year generating unit lifetimes. As figure ES-4 indicates, sulfur dioxide emissions thus decrease under the first two scenarios and increase slightly under the last scenario.

Figure ES-6
Electric Utility Sulfur Dioxide Emissions in the ORBES Region, Base Case and SIP Noncompliance Case



However, given the costs of installing new generating capacity and the costs of complying with the stricter NSPS and RNSPS controls, it is quite possible that utilities may postpone the retirement of SIP units. Under two scenarios--noncompliance and high growth--this possibility was examined briefly. Figure ES-5 indicates the sulfur dioxide emission levels that would occur under noncompliance if 35-, 45-, or 55-year generating unit lifetimes are assumed. Figure ES-6 compares the high growth case that assumes 45-year lifetimes with a variation that is identical except for a 35-year lifetime assumption. Both of these figures demonstrate the difference that early retirement of SIP units could have on regional sulfur dioxide emission levels.

The periodic maintenance of an existing plant can result in a substantial renovation of that plant. The effect of such an alteration is that the plant may not be retired as early as it would have been otherwise. If, however, certain modifications were considered major enough to warrant the reclassification of SIP units from an existing to a new source category, such a revised definition might result in a utility's evaluation of the relative merits of (1) continuing to use an existing unit or (2) building a new unit. If existing SIP units were retired through such an evaluation, substantial emission reductions could result.

The 35-year retirement of SIP units still would not wholly alleviate the air quality problems stemming from regional sulfur dioxide emissions. Even in 2000, SIP-regulated units would account for the bulk (at least 67 percent) of utility sulfur dioxide emissions, regardless of whether a 35- or 45-year life is assumed. However, SIP units would account for no more than 28 percent of the electrical generation in the year 2000 under any of the coal-dominated scenarios. Thus, the emissions contributed by SIP units would be disproportionate to the benefits of SIP generation in the year 2000. SIP units comprise such a major portion of the total utility emissions in 2000 and such a low percentage of the generation because they emit about five to six times more sulfur dioxide than a new plant supplying the equivalent amount of electricity.

Stricter Controls. One way to achieve a more balanced emission-generation ratio would be to make stricter the SIP compliance strategies currently in existence. The strict environmental control case offers an example of what might be expected if such stricter controls were enacted and enforced. This latter case assumes that in each ORBES state the urban SIPs--which are stricter than rural SIPs--would be applied throughout the ORBES portion of that state. As a result of such strict controls, by the year 2000, sulfur dioxide emissions would decrease more under this scenario than under any other coal-dominated scenario. Moreover, the rate of decrease would be more rapid (see figure ES-4).

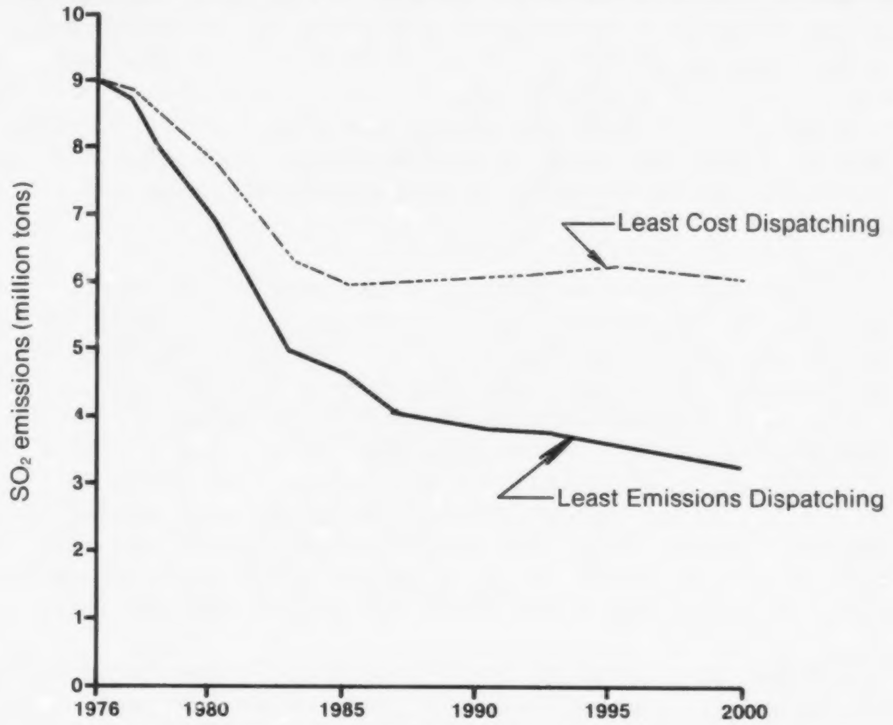
Least Emissions Dispatch. Another way to achieve a more balanced emission-generation ratio would be to use least emissions dispatching. At present, and under all of the coal-dominated scenarios, generating units are loaded (brought on-line) in order of operating costs. As a result, SIP units generally are the first units dispatched, since, as discussed previously, newer units are more expensive to operate. Under the high growth case, a variation was examined that assumed coal-fired units would be dispatched according to least emissions of sulfur dioxide. Under the least emissions criterion, the units emitting the most sulfur dioxide (on a per Btu basis) would be loaded last. Under one such dispatching order, for example, RNSPS units might be dispatched first, then NSPS units, then urban SIP units, and finally rural SIP units. However, such a dispatching order may not always be feasible.

Under this least emissions policy, total regional utility sulfur dioxide emissions would be 55 percent lower than they would be under the least cost policy in the year 2000 (see figure ES-7). SIP emissions alone would be 35 percent lower under the former case than under the latter case. Moreover, in the year 2000 under the least emissions dispatching variation, a more balanced emission-generation ratio would be achieved. Under least emissions dispatching, SIP units would emit 1.5 million tons of sulfur dioxide--or 45 percent of all utility sulfur dioxide emissions--and generate about 171 million megawatt hours. Under the least cost policy, on the other hand, SIP units would emit 4.32 million tons of sulfur dioxide--or 71 percent of the total emissions--and generate only about 162 million megawatt hours.

As this discussion of sulfur dioxide emissions under the different coal-dominated scenarios thus has revealed, the current emission standards, if complied with, would reduce total sulfur dioxide emissions between 1976 and 1985 from the 1976 levels. Any further reductions would be determined by the lifetime of SIP plants. As will be discussed shortly, such further reductions would be important since episodic concentrations still would result from the 1985 emission levels of most of the scenarios. Before such concentrations are discussed, however, particulate and nitrogen oxide emission trends under these coal-dominated scenarios are examined.

PARTICULATE EMISSIONS. Utility particulate emissions would be reduced significantly by the year 2000 from the 1976 levels under all of the coal-dominated scenarios except the noncompliance case. Moreover, except under the latter scenario, particulate emissions would be reduced at about the same rate and would be about the same in 2000--nearly five times lower than the 1976 emissions (see figure ES-8). In addition, such variations as least emissions dispatching would result in emissions about the same as those charted in figure ES-8. Noncompliance, however, would result in increased particulate emissions through 1985. In 2000 under noncompliance, particulate emission levels would be only slightly lower than the 1976 levels. These scenarios

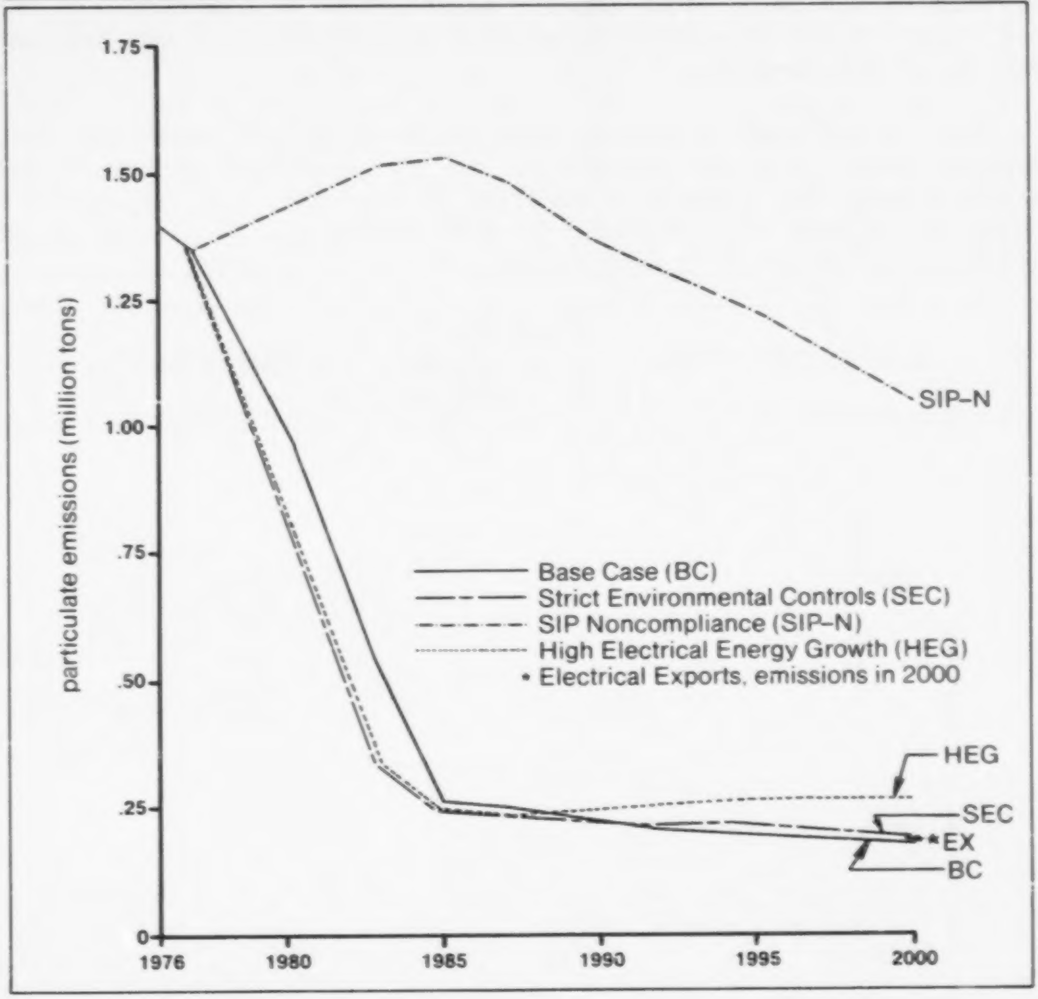
Figure ES-7
Electric Utility Sulfur Dioxide Emissions in the ORBES Region, Dispatching Variations under High Electrical Energy Growth



thus suggest that current particulate standards--which are the same in urban and rural settings--will be effective. One major reason for this effectiveness, however, is that particulate removal technology is assumed to be between 85 and 94 percent efficient depending on when the unit was built.

NITROGEN OXIDE EMISSIONS. All scenarios would result in increased utility nitrogen oxide emissions. Similarly, except under the high electrical energy growth scenario, utility nitrogen oxide emissions would increase at about the same rate through 1985 and would be nearly the same in 2000—approximately 35 percent higher than 1976 emissions (see figure ES-9). There are two reasons for the similarity among scenarios. First, nitrogen oxide emission limits do not exist for SIP plants in the ORBES region, except in the urban areas of Illinois. Second, the same emission limits were assumed for new units under all scenarios. Thus, nitrogen oxide emissions would increase from the 1976 levels primarily in proportion to electricity demand growth and to the lifetime of SIP units. This fact also explains why, after 1985, nitrogen

Figure ES-8
Electric Utility Particulate Emissions in the ORBES Region, Coal-Dominated Scenarios

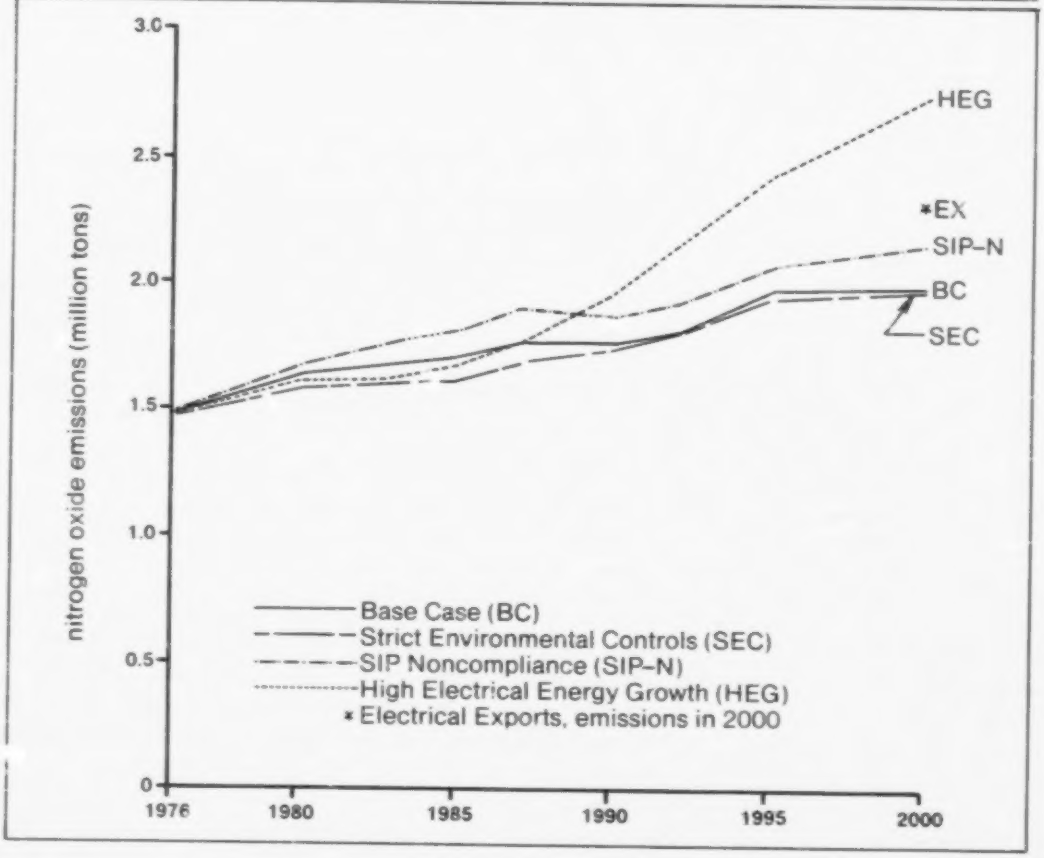


oxide emissions would increase under the high electrical growth case at a faster rate than under the other scenarios: the high growth case has the highest electricity demand growth and assumes 45-year SIP unit lifetimes instead of the 35-year lifetimes assumed under the other coal-dominated scenarios.

POLLUTANT CONCENTRATIONS. The magnitude of changes in utility sulfur dioxide emission levels under each scenario corresponds to changes in annual average (or long-term) and episodic (short-term) regional sulfur dioxide and sulfate concentrations. Moreover, since, as discussed earlier, the transformation of sulfur dioxide into sulfates contributes to concentrations of total suspended particulates, reductions in both utility particulate emissions and utility sulfur dioxide emissions could reduce measured TSP concentrations. However, the ratio of the lower ORBES region's contribution to concentrations in the upper region is not likely to change from the ratio during the base period under any of the scenarios.

Many of the same statements made about emissions under the various scenarios also apply to comparisons of the scenarios and their annual concentrations. For example, regardless of scenario, the regional sulfur dioxide and sulfate concentrations in 2000 attributable to utility emissions

Figure ES-9
Electric Utility Nitrogen Oxide Emissions in the ORBES Region, Coal-Dominated Scenarios



would be lower than the present concentrations. Again, it is the strict environmental control case that would reduce the annual average concentrations the most and that would reduce them more rapidly than any of the other scenarios (see table ES-2). Similarly, the high electrical energy growth case and the noncompliance case would result in the least reduction by the year 2000. In fact, the 1976 concentrations would even increase through 1985 under the noncompliance case. In general, most concentration reductions would occur by 1985—regardless of scenario--if SIP plants have complied by that date. Figures ES-10 and ES-11 illustrate the reductions in annual average sulfur dioxide and sulfate concentrations under the base case in 2000 as compared with the 1976 concentrations.

Another benefit of lower utility sulfur dioxide emissions is the probable reduction of the concentrations that would occur under episodic conditions. If the characteristics of the August 27, 1974, sulfate episode were to be repeated in 2000 under any of the scenarios, the predicted utility-related, short-term sulfur dioxide and sulfate concentrations would be reduced from the utility-related, short-term concentrations that were registered during that episode (see table ES-3). However, since these short-term concentrations were quite high during the August 27 episode (the most frequently occurring type of episode in the ORBES region) even the 49 and 51 percent reductions that would occur in 2000 under the base case would result in short-term sulfur dioxide levels on the order of 30 micrograms per cubic meter and in short-term sulfate levels that would be considered marginally episodic--that is, on the order of 15 micrograms per cubic meter over a large area. On the other hand, the strict environmental control case would lead to reductions of such magnitude that the short-term levels of sulfur dioxide and sulfates no longer would be

Table ES-2
Sulfur Dioxide and Sulfate Annual Average Concentrations, ORBES Region, Percent Change from 1976, Highest Concentration Region

Pollutant	Concentration, 1976 (μg/m³)	Year	Base Case	Strict Environmental Controls	SIP Noncompliance	High Electrical Energy Growth
			(%)			
Sulfur dioxide	25.88	1985	−28	−62	+16	−30
Sulfur dioxide	25.88	2000	−50	−71	−18	−29
Sulfates	9.2	1985	−27	−56	+13	−25
Sulfates	9.2	2000	−49	−66	−20	−25

Figure ES-10
Annual Average Sulfur Dioxide Concentrations, Electric Utility Contribution

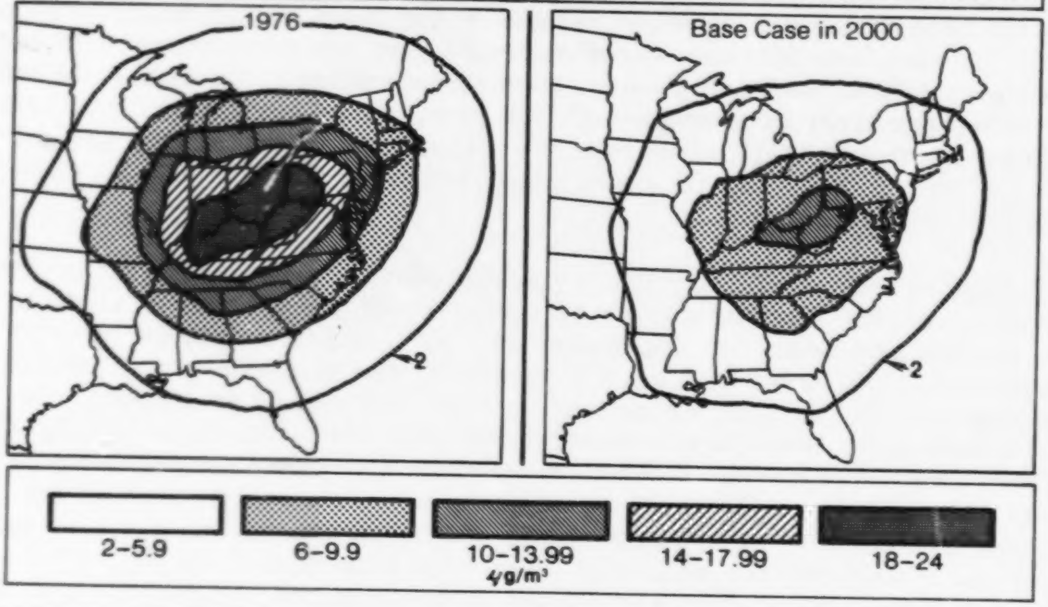
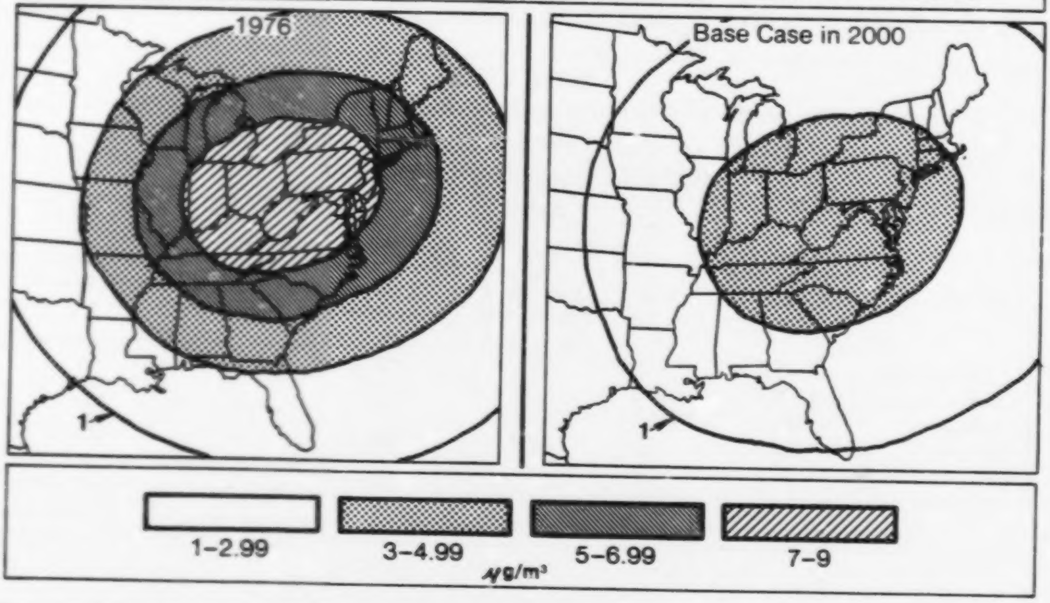

1976
Base Case in 2000
2
2
2-5.9
6-9.9
10-13.99
14-17.99
18-24
μg/m³

Figure ES-11
Annual Average Sulfate Concentrations, Electric Utility Contribution


1976
Base Case in 2000
1
1
1-2.99
3-4.99
5-6.99
7-9
μg/m³

considered episodic. As can be deduced, therefore, the noncompliance and the high growth cases, which reduce emissions the least by 2000, would result in relatively high episodic concentrations.

Annual average and episodic concentrations are important in terms of both regional crop loss impacts and regional health impacts (among other things) since the reductions in concentrations consistently correlate with less crop loss and fewer health impacts.

PHYSICAL CROP LOSSES. In terms of agricultural impacts, studies have indicated that sulfur dioxide concentrations as low as 130 micrograms per cubic meter (one-tenth of the secondary three-hour standard) in the presence of moderate ozone levels (0.06 to 0.1 parts per million) can affect vegetation. Thus, three coal-dominated scenarios--the base case, the noncompliance case, and the high growth case--were examined to determine the regional acreage that could be affected by the sulfur dioxide concentrations attributable to ORBES-region utility emissions. Each of these three scenarios also was examined to determine the impact of such affected acreage on crop yields, and it was found that crop yield losses would not be as high in both 1985 and 2000 as they were in 1976. However, because utility sulfur dioxide emissions would be higher under the noncompliance case and because more acreage would be affected by the resulting sulfur dioxide concentrations of 130 micrograms per cubic meter, noncompliance would result in the highest losses. Nevertheless, regardless of the scenario, physical crop losses related to utility sulfur dioxide emissions would represent less than 1 percent of the expected regional yield in any given year. Thus, from this regional perspective, the direct effects of sulfur dioxide emissions in the ORBES region on agricultural losses can be thought of as negligible under all three of these scenarios.

Table ES-3
Sulfur Dioxide and Sulfate Episodic Concentrations, ORBES Region, Percent Change from August 27, 1974, Episode, Highest Concentration Region

Pollutant	Concentration, 1976 (µg/m)	Year	Base Case	Strict Environmental Controls	SIP Noncompliance	High Electrical Energy Growth
			(%)			
Sulfur dioxide	94.04	1985	–31	–68	+18	–34
Sulfur dioxide	94.40	2000	–49	–75	–13	–30
Sulfates	40.10	1985	–25	–76	+16	–23
Sulfates	40.10	2000	–51	–78	–30	–18

The majority of regional crop losses are the result of oxidants formed from hydrocarbons and from nitrogen oxide emissions. Nitrogen oxide emissions in the ORBES region originate primarily from transportation and from electrical generation. However, it is projected that nitrogen oxides from transportation will decrease significantly by the year 2000. Thus, utility nitrogen oxide emissions will begin to constitute a larger proportion of the regional nitrogen oxide emissions, especially since nitrogen oxide standards do not yet exist for SIP units in the ORBES region and since SIP-unit emissions are projected to account for the majority of all utility emissions. As a result, the rate of decrease in ozone production as well as the rate of decrease in ozone-related crop losses may be dictated by utility nitrogen oxide emissions.

In general, regardless of the scenario, losses due to oxidants would constitute about 99 percent of all the losses expected because of sulfur dioxide and ozone. Moreover, the distribution of the losses due to oxidants would vary among state portions. However, the ORBES state portions of Illinois, Indiana, and Ohio would account for about 95 percent of both sulfur dioxide and ozone losses. Finally, the distribution of all crop losses due to air pollution is not merely a local problem--that is, merely in the vicinity of a power plant--but, because of pollutant transport, these losses may occur in areas removed from major point sources. The dollar losses related to crop losses due to sulfur dioxide and all oxidants are given in section 6.2.

MORTALITY. Substantial controversy exists about the quantification of deaths related to air quality. Yet increasing evidence exists to support the hypothesis that the annual average exposure to sulfates--or something closely related to them--results in an increased mortality rate. Therefore, cumulative sulfate-related deaths between 1975 and 2000 were projected for the coal-dominated scenarios. Such projections depend on the damage function employed since rates between 0 and 9 per 100,000 persons exposed per microgram of sulfates per cubic meter are found in the literature. If a rate of 3 is used, it becomes clear that the magnitude of utility emissions is a dominant factor: the strict control case would result in the lowest number of cumulative deaths, while the noncompliance case and the high growth case would result in the most such deaths. Cumulative sulfate-related deaths under the latter two scenarios also would be nearly 34 and 13 percent higher, respectively, than would the deaths under the base case.

6.2 Economic Impacts Related to Air Quality Impacts

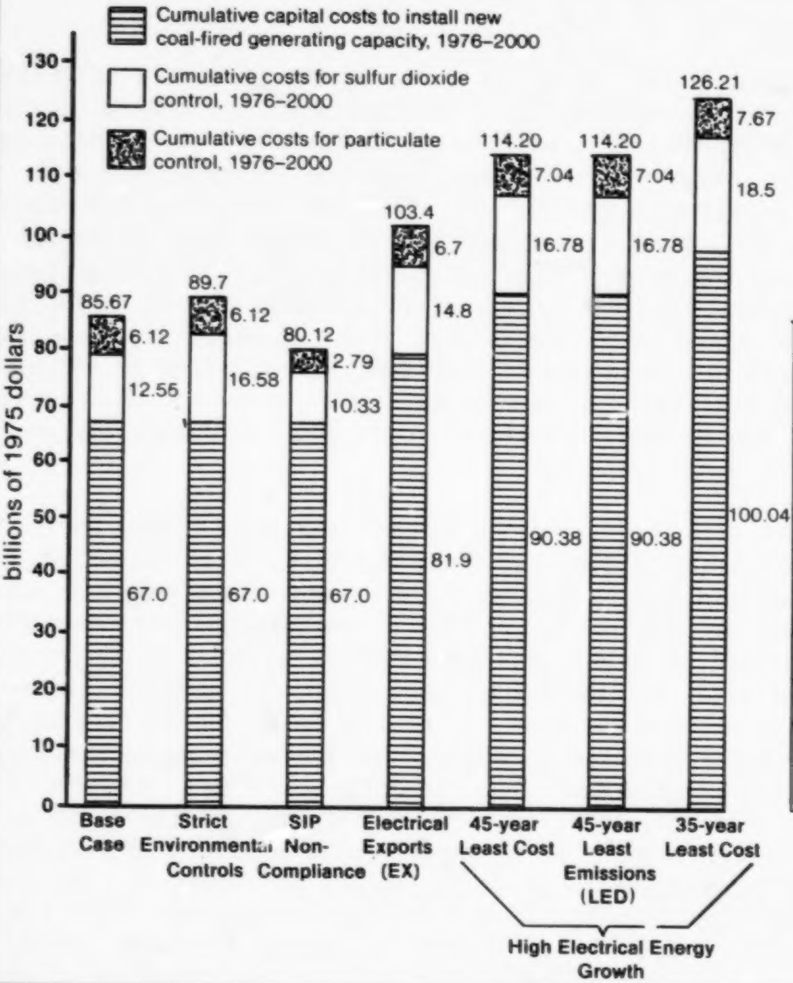
The costs to the utilities and to the consumer of the possible reductions in emissions and other air-related impacts also were projected for the five coal-dominated scenarios as well as for the least emissions variation and the high electrical energy growth case with a 35-year lifetime variation. Agricultural monetary losses also were estimated for three scenarios--the base case, the noncompliance case, and the high growth case. Knowing these costs permits comparisons to be made among the scenarios in terms of the social benefits derived from reduced emissions versus the economic impacts of such reductions.

UTILITY COSTS. Figure ES-12 charts the costs to the utilities of installing new coal-fired generating capacity, of installing pollution control devices on these new units, and of retrofitting existing units. As shown in this figure, the base case, the strict control case, and the noncompliance case would result in the same capital costs but in different pollution control costs. The differences in pollution control costs among these three scenarios would result entirely from the retrofitting of existing SIP plants with pollution control devices. Thus, the total cumulative pollution control costs for the base case would be higher than those under the noncompliance case because under the base case about one-third of existing capacity would be retrofitted. Under the strict control case, on the other hand, almost all of the existing capacity would be retrofitted, resulting in the highest cumulative pollution control costs of the three scenarios.

The high growth case and its variations and the export case would result in higher costs to the utilities than would the first three scenarios. These higher costs, however, would be due to the costs of installing the expanded generating capacity and the pollution control devices on this new capacity. Thus, if the proportion of pollution control costs to total capital costs is examined, the base case and the high growth case are similar: under both scenarios, pollution control costs would total about 21 to 22 percent of the total costs. It should be noted, however, that these total capital costs do not reflect the operating costs. The operating costs are included in the calculation of the price of electricity, which reflects all the costs borne by the utilities each year. Thus, for example, while the high growth scenario and the high growth least emissions variation are projected to have the same capital costs, there would be differences in their operating costs since the least emissions dispatching variation would require increased operation of pollution control devices and the burning of greater quantities of cleaned or low-sulfur coals.

CONSUMER COSTS. The direct costs to the consumer would increase regardless of scenario. In the short run, however, some scenarios may result in a faster rate of increase in the price of electricity (see figure ES-13). Several observations can be made about the electricity prices and their rate of increase. For one, between 1976 and 1985, the price of electricity rises according to the added costs of complying with SIP emission limits, paying for rising fuel and capital costs, and meeting electricity demand. Thus, as figure ES-13 indicates, the price of electricity between 1976 and 1985 would

Figure ES-12
Cumulative Capital Costs, Coal-Dominated Scenarios, 1976–2000

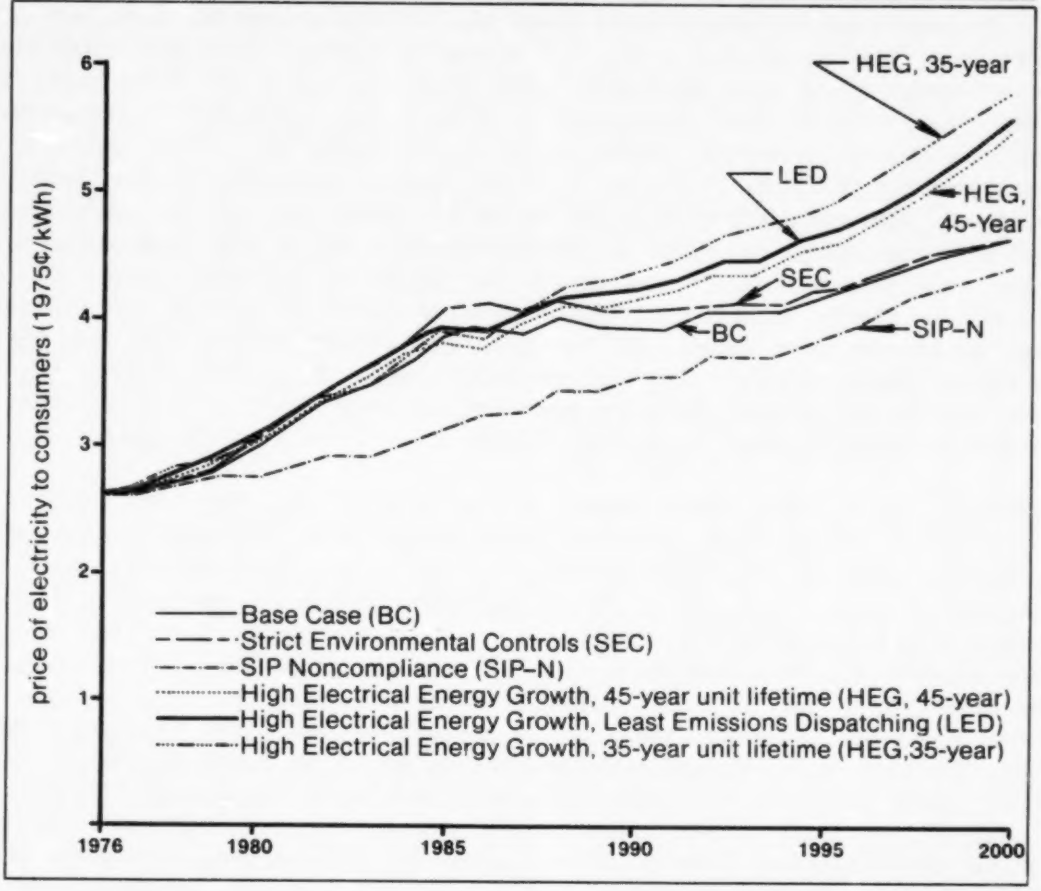


Cumulative sulfur dioxide and particulate control costs

Scenario	costs billion $	% total costs
BC	18.67	21.8
SEC	22.7	25.3
SIP–N	13.12	16.4
EX	21.5	20.8
HEG	23.82	20.9
LED	23.82	20.9
35-Year	26.17	20.7

rise similarly when nearly the same degree of compliance is assumed--that is, under all the scenarios but the noncompliance case. The strict environmental control case, however, would result in the greatest increase in electricity prices since complying with stricter SIP standards would cost the utilities more. The price of electricity under the noncompliance case, of course, reflects the absence of such control costs.

Figure ES-13
Electricity Prices in the ORBES Region, Coal-Dominated Scenarios



Between 1985 and 1995, the rise in electricity prices depends on the annual electricity demand growth rate, capacity replacement, and capacity expansion. Since the base case, the strict control case, and the noncompliance case assume nearly the same replacement, expansion, and growth rates, the price of electricity would rise little between these years. Under the high growth scenario and its variations, however, the price of electricity rises between 1985 and 1995 since more capacity expansion is projected under these scenarios. The greater operating costs of least emissions dispatching also are reflected in the higher price of electricity under this variation.

Between 1995 and 2000, all scenarios show a rise in the price of electricity. This increase would result because additional generating units must be constructed to satisfy electricity demand after the year 2000 and because a significant number of SIP units will retire during these years and must be replaced.

Because some scenarios would cause electricity prices to be higher in the short run, the cumulative costs to consumers between 1976 and 2000 give a better idea of the total consumer costs than the price of electricity in a given year. Under the compliance or base case, such cumulative revenues required from consumers would total $525 billion (1975 dollars, or approximately $709 billion in 1979 dollars). Compared to the base case revenues, the cumulative revenues required under the strict environmental control case would be about 4 percent higher, while the revenues required under the noncompliance case would be about 10 percent lower. A high electrical energy growth rate would require about 18 percent more revenues than would the base case. Of the two high growth variations, the 35-year variation would require the most revenues (about 21 percent higher than the base case), while the revenues required by the least emissions dispatch variation would be about 19 percent higher than under the base case.

MONETARY CROP LOSSES. When comparing the agricultural monetary losses that would occur because of physical crop losses due to sulfur dioxide and oxidants, some of the same statements made under the physical crop loss discussion can be repeated. First, monetary losses of oxidant-related crop losses would constitute virtually all (about 99 percent) of the economic losses under all of these scenarios. In addition, monetary losses related to the crop losses due to sulfur dioxide emissions would be similar under the three scenarios examined (less than 1 percent of the total monetary losses). Also, the total agricultural monetary losses would be concentrated in certain ORBES state portions (Illinois, Indiana, and Ohio) regardless of scenario. Finally, the high growth case would result in the highest cumulative agricultural monetary losses ($8.4 billion in 1975 dollars, or approximately $11.3 billion in 1979 dollars). The base case and the noncompliance case would result in about the same cumulative agricultural monetary losses ($7 billion in 1975 dollars, or approximately $9.5 billion in 1979 dollars).

6.3 Other Impacts Related to Expanded Capacity

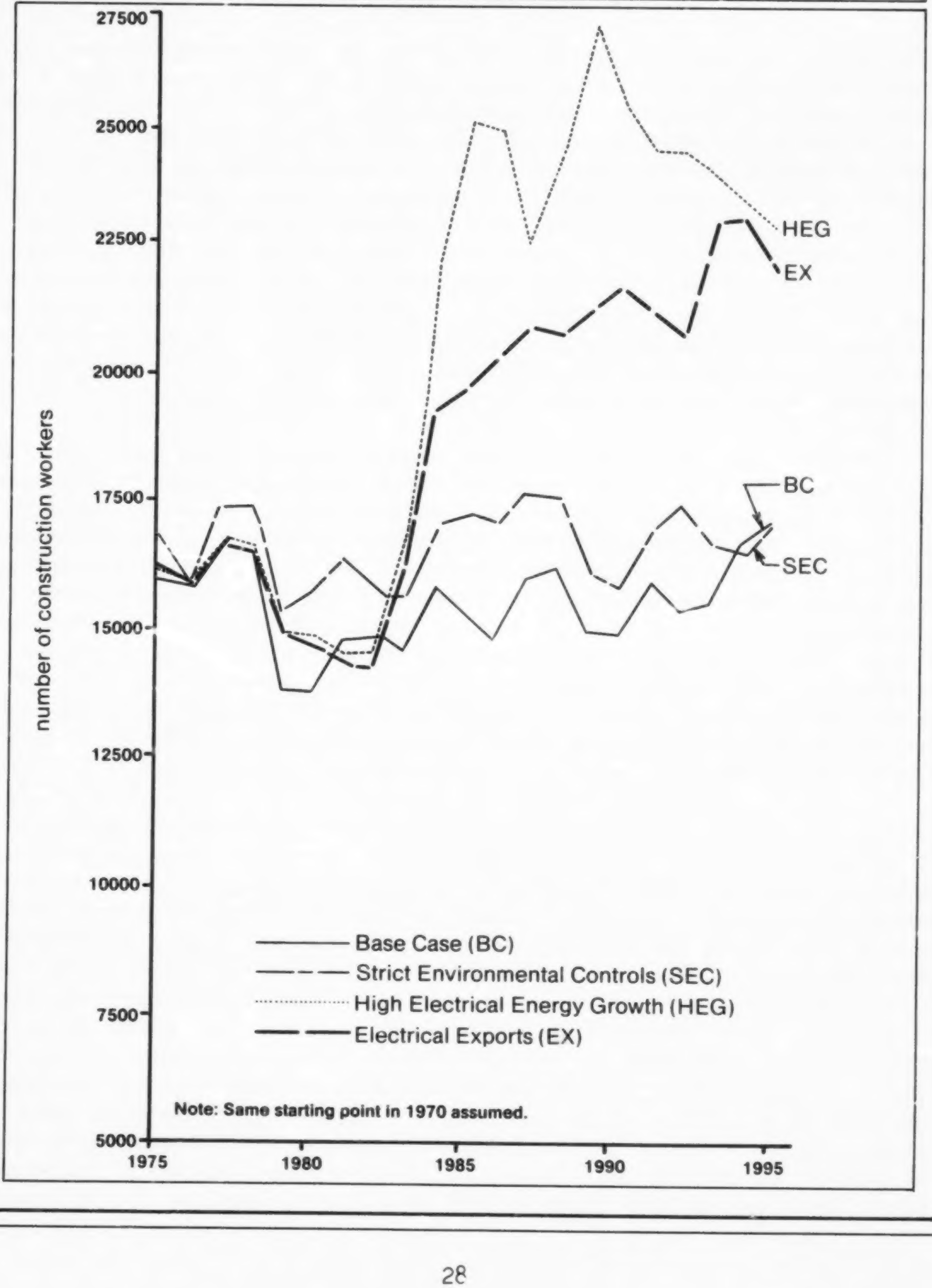
LAND. The regional impacts of an expanded utility industry on land use would be about the same for three of the coal-dominated scenarios--the base case, the strict environmental control case, and the noncompliance case--since their generating capacity is about the same and their siting patterns somewhat similar. The base case, for example, converts about 184,000 acres, or 0.15 percent of the ORBES region, for generating facility use through 2000. However, although the regional acreage affected would be about the same under all three cases, affected acreage at the state level would vary slightly. Policies that encourage high electrical energy growth or the export of electricity from the region would result in much larger generating capacities than the three other coal-dominated scenarios. Thus, the land converted would be about 30 percent higher under the high growth case than under the base case; under the export case, land conversion would be about 17 percent higher than it would be under the base case.

EMPLOYMENT. An increase in the employment of power plant construction and operation workers would be expected under both the high electrical energy growth case and the electrical exports case. In fact, such employment would rise dramatically under these two scenarios between 1983 and 1987, although the high growth scenario would require more workers than the export case (see figure ES-14). However, such rapid changes as occur under the high growth case could result in short-term labor shortages followed by a surplus of labor as experienced workers have a choice of jobs and then few choices. Moreover, shortages of the skilled labor necessary to power plant construction and operation--such as boilermakers, pipefitters, and electricians--might accompany the high growth case. In general, however, skilled labor shortages would not be a major problem for the region under any of the other coal-dominated cases, although local shortages could possibly occur.

Annual coal production in the region for all purposes and mining employment would increase under the base case, the strict environmental control case, and the electrical exports case. However, annual coal production would be much higher in 2000 under the electrical exports case than it would be under the other two scenarios. Thus, regional mining employment would rise similarly under the base case and the strict control case, from a minimum of 36 percent to a maximum of about 226 percent, depending on the county. Such employment would increase from a minimum of 42 percent to a maximum of 270 percent under the electrical exports case. It is also projected that at least 79 to 88 of the 152 ORBES counties with a concentration in coal mining would experience boom-town effects (growth over 200 percent) under all three of these scenarios.

HEALTH. Under all of the coal-dominated scenarios, the health impacts related to supplying coal to ORBES power plants would increase. This increase results because, under all scenarios, coal production as well as electric utility coal consumption would rise from current levels. In 1985, the increases in the health impacts in the coal-mining and coal-processing sectors would be the same under all coal-dominated scenarios. In 2000, three of the scenarios--the base case, the strict control case, and the noncompliance case--would result in similar health impacts in these sectors, while the high growth case and the exports case would result in impacts about 17 percent higher. The health impacts in the coal transportation sector were analyzed only for the base case and the strict control case and only for the year 2000. Both cases would result in an increase in the fatalities associated with transport to ORBES electrical generating facilities, but in the same number of injuries as currently since railroad injuries are projected to decline at a greater rate than fatalities.

Figure ES-14
Construction Workers, Coal–Dominated Scenarios, 1975–95



Note: Same starting point in 1970 assumed.

WATER QUALITY. A comparison of the water quality analyses conducted for the coal-dominated scenarios reveals that none of these scenarios would result in aquatic habitat impacts very different from each other or from those that could have occurred in 1976 under 7-day-10-year low flow conditions. Thus, whether historical municipal and industrial growth continues, or whether low, high, or base case electricity demand occurs, the region already appears to have the potential to experience its most serious aquatic habitat impacts under 7-day-10-year low flow conditions. However, although overall aquatic habitat impacts change little under most of these scenarios, under the strict control case and the high growth case, some rivers would register perhaps slightly less or more stress than they would under the base case.

Background Concentrations. The reason why the majority of the streams would experience the same impacts under the scenarios as they would under 1976 conditions concerns the high background concentration levels that exist in the region. As noted under the base period discussion (sec. 3), 19 of the 24 streams studied could have violated several of the study's reference concentrations under 7-day-10-year low flow at some time in 1976. Further, the overwhelming majority of these high background concentrations are estimated to be geochemical or to originate from nonpoint sources under conditions of higher flow. Since the likelihood of bringing nonpoint sources under control during the time frame of this study is considered almost impossible by most experts, background levels in the ORBES streams were projected to remain constant between 1975 and 2000 under all scenarios except the strict control case. Under the strict control case it was assumed that background levels would be reduced by half by the year 2000. (It also was assumed under this case that power plant effluent loadings would be reduced 95 percent from the base case loadings.) Such calculations reveal that if such a reduction were to occur, aquatic habitat impacts would remain about the same although slightly less stress would be experienced on all rivers. The results under the strict control case thus suggest that background levels are so high that they would have to be reduced by more than half to avoid serious aquatic habitat impacts under 7-day-10-year low flow conditions.

Loadings. The influence of these background concentrations is further indicated when the effluent loading assumptions of these scenarios are compared. Under all of the coal-dominated scenarios except the strict environmental control case, power plant effluents were not limited. The strict control case, however, along with its assumption of reduced concentrations, assumed that energy conversion facilities would operate at 5 percent of base case levels. However, a comparison of the strict control case with the other coal-dominated cases--the base case, for example--reveals little difference because of the loading assumptions. Although slightly less stress would occur on all rivers under strict controls, aquatic habitat impacts remain the same as under the base case on all but four rivers. If the impacts under the strict control case then are compared to those that could have occurred in 1976, only two rivers would register changes from the 1976 aquatic habitat impacts. Thus, since loading is not a significant factor, background concentrations appear mainly responsible for the substantial impacts that could occur under 7-day-10-year low flow conditions.

Consumption. Power plant consumption would be important on those of the region's smaller streams where little municipal and industrial consumption occurs and where flow under 7-day-10-year low flow conditions would be curtailed drastically. However, if background concentrations were not so high on these small streams, power plant consumption might have little impact. Thus, once again the high background levels are more important than the consumption source.

What the impacts on these small streams suggest is that alternative siting or technology could alleviate almost all power-plant-related impacts on water quality under all scenarios. There is, however, one, perhaps significant, problem with alternative siting of power plants. Although water quality would be protected, air quality would suffer since most of the suitable alternative sites in terms of water quality are located along the Ohio River main stem, where air quality problems exist. A further concentration of power plants in this area thus could exacerbate these air quality problems.

What can be done to avoid the combined effects of natural forces and high background concentrations thus is hard to pinpoint, especially if it is unlikely that nonpoint sources can be brought under control. Preventing the rather minor power-plant-related impacts would necessitate the tradeoff just discussed. Avoiding the potentially significant impacts of municipal and industrial consumption also would involve tradeoffs. If, for example, regulatory bodies were to implement siting restrictions that prohibit the siting of any entity that consumed water along streams having 7-day-10-year low flows less than 100 cubic feet per second, a number of rivers would not be available for growth of any kind. This condition would result in a very limited number of sites for industry, especially for power plants. Thus, as this brief outlining of some possible steps and their limitations suggests, improvements in water quality may require some environmental, social, and economic tradeoffs that would have their own repercussions.

7. MITIGATION STRATEGIES

On a regional scale, existing institutional mechanisms are inadequate to ameliorate air quality impacts, many of which transcend political boundaries both inside and outside the ORBES region, particularly to the northeast.

TECHNICAL STRATEGIES. A variety of technical strategies, usually applied on a plant-by-plant basis, could be more effective if implemented regionally.

Among the technical strategies discussed in the context of the ORBES scenarios (see sec. 6.1) are the use of flue gas desulfurization systems, or "scrubbers"; least emissions dispatching; modified plant retirement schedules; and stricter environmental standards.

TECHNO-ORGANIZATIONAL STRATEGIES. In contrast to technical strategies, which usually are applied at single generating units or within a single utility service area, techno-organizational strategies are broader and could be developed on an interstate, multistate, or regional scale. The need for such strategies arises from transboundary air pollution transport, which can be divided into two types: (1) *local* transboundary air pollution transport (the movement of air masses is over relatively short distances across state lines and the contributions from individual plant sources usually can be identified) and (2) *long-range* transboundary air pollution transport (the air masses travel longer distances, often across several state lines, and the contributions from individual sources are difficult to isolate).

Local Transboundary Transport. Local transboundary air pollution transport is treated in the Clean Air Act, in provisions that attempt to make a state responsible for pollution that originates within its borders but is transported short distances into other states. At present, action is pending on at least three petitions filed by several ORBES-region states in regard to air pollution generated by power plants in neighboring states. Protracted legal proceedings on related local transboundary pollution questions also have taken place in the region within the context of the Clean Air Act.

Long-Range Transboundary Transport. Long-range transboundary air pollution transport, on the other hand, is not covered specifically in the Clean Air Act. However, as discussed previously (sec. 6.1), long-range transport contributes to violations of NAAQS in the upper ORBES region. Thus, air quality in the ORBES region and beyond could be improved if there were a regionwide techno-organizational strategy for determining expected emissions from coal-burning plants, siting new plants, and operating both existing and new facilities. A coordinated strategy is necessary because of the interdependency of emission reductions, siting, and operations.

A coordinated siting mechanism could help to reduce pollutant concentrations at local "hot spots," where these concentrations are highest. However, total regional pollutant loadings would remain the same whether a regional siting mechanism is developed or not. Thus, regional coordination appears to be required to reduce pollutant loadings and/or to reduce concentrations from long-range transboundary pollution in the ORBES region and beyond.

Utilities and State Governments. If new organizational approaches are to be devised in a meaningful way, both the states and the electric utilities must participate. Voluntary cooperation among utility companies is one possibility, but it may not be realistic to expect utilities in different states to work together in activities aimed at the mitigation of negative transboundary air quality impacts. Moreover, cooperation would have to encompass operations as well as siting if extraregional impacts were to be mitigated.

If utilities were to agree upon the desirability of cooperation in either siting or operations across state lines, the most appropriate organizational arrangements are not clear. At present, utilities are regulated by individual states, and most utility service areas follow state lines. Thus, voluntary cooperation across state lines probably would be difficult. Yet the utilities do engage in interstate cooperation in several other areas, principally in the assurance of electric power reliability. It is conceivable that regional reliability councils now in operation could stimulate further cooperation. Indeed, the expansion of existing federal legislation might encourage cooperative siting, if not cooperative operations. Cooperation among the states in this regard also should be examined, but prospects do not appear promising. In only one ORBES state, Ohio, has the legislature mandated admininstrative leaders to seek cooperation with other states in developing mitigation strategies. Ohio is also the only ORBES state with a "one-stop" siting procedure; if similar arrangements existed in the other ORBES states, they might provide a vehicle for interstate discussions on siting problems.

Interstate Compacts. Another potential vehicle is the interstate compact. For example, an existing compact, the Ohio River Valley Water Sanitation Commission (ORSANCO), might be expanded in scope to permit supplementary agreements, between two or more member states, to resolve transboundary air pollution conflicts and other problems related to interstate facility siting and possibly operations.

No interstate compact to mitigate long-range transboundary air pollution is known to operate anywhere in the country at this time. However, the Delaware River Basin Compact has organizational elements that could be relevant in the consideration of such a mechanism for the ORBES region. For example, the Delaware compact has been instrumental in obtaining interstate approval of power plant sites.

Other Regional Bodies. The Tennessee Valley Authority (TVA) cannot be ignored in any consideration of mitigation strategies. A portion of Kentucky is included in the TVA area, and problems of long-range transboundary air pollution transport are shared by the TVA area and the ORBES region. In fact, the two areas are connected in so many ways as to make separate treatment impossible.

Other regional bodies that should be considered in this context are the Ohio River Basin Commission and the Appalachian Regional Commission (ARC). Some have suggested that the ARC's functions be expanded so that this organization could address air impacts in the Ohio River valley and perhaps participate in interstate siting. However, the proposal has found little support.

Federal Action. The most likely federal initiatives will center on the Clean Air Act; an upcoming debate in Congress will review the entire act, including the 1977 amendments. The most extreme possibility, federal preemption, is considered unlikely.

8. FUEL SUBSTITUTION AND CONSERVATION SCENARIOS

Four scenarios investigate energy and fuel use characteristics that differ from those of the coal-dominated scenarios (see table ES-1). Three of the cases assume relatively less emphasis on coal use for electrical generation because of partial substitution by other fuels. In the natural gas substitution case, natural gas is substituted for other fuels whenever practicable, but not to fire utility boilers. In the nuclear fuel substitution case, nuclear-fueled electrical generating capacity substitutes directly for coal-fired capacity. In the alternative fuel substitution case, a variety of alternative fuels, including biomass and solar energy, partially replace coal-fired capacity. The fourth case assumes that energy growth in the ORBES region is significantly less than under all other scenarios because of the implementation of conservation measures. All four cases are compared with the coal-dominated base case.

The same regional population, fertility, and economic growth rates are assumed in the four scenarios discussed here as are assumed in the coal-dominated case. Moreover, base case environmental controls are assumed under all four scenarios. Finally, the same assumptions as under the coal-dominated scenarios are made concerning the mining for utility coal and the utility-announced capacity.

9. COMPARISON OF FUEL SUBSTITUTION AND CONSERVATION SCENARIOS

An analysis of these fuel substitution and conservation scenarios suggests that all of these scenarios would reduce the emission-related impacts that are projected to occur under the coal-dominated base case. Other across-the-board comparisons, however, are more difficult to make.

9.1 Emissions, Concentrations, and Air-Quality-Related Impacts

EMISSIONS. Utility sulfur dioxide emissions would be only slightly lower in 2000 under the fuel substitution and conservation scenarios than under the base case (see table ES-4) even though substantially fewer coal-fired units would be added under the substitution and conservation scenarios. The conservation case would reduce sulfur dioxide emissions the most (resulting in emissions 11 percent lower than under the base case), and the nuclear substitution case would reduce them the least (resulting in emissions only 3 percent lower).

The expanded use of SIP generating units under each of the fuel substitution and conservation scenarios explains why these scenarios would result in sulfur dioxide emissions quite similar to those of the base case. Under both the conservation emphasis case and the natural gas substitution case, fewer new generating units would be built than under the base case; under the nuclear fuel substitution case, new units added after 1985 would be nuclear fueled rather than coal fired. As a result, SIP-regulated generating units would be used more than they would under the base case, where some of the electrical generation shifts to the new, cleaner RNSPS units. For example, under the natural gas substitution case, SIP units would account for 32 percent of the electrical generation in the year 2000, whereas they would account for 25 percent under the base case. Thus, while sulfur dioxide emissions from SIP-regulated units would account for 67 percent (or 2.93 million tons) of the sulfur dioxide emitted in 2000 under the base case, under the natural gas case such emissions not only would be higher (3.05 million

Table ES-4
Sulfur Dioxide, Particulate, and Nitrogen Oxide Emissions, ORBES Region, Fuel Substitution and Conservation Emphasis Scenarios, Year 2000

	Sulfur Dioxide Emissions	Particulate Emissions (millions of tons)	Nitrogen Oxide Emissions
1976	8.94	1.38	1.49
Base Case	4.35	0.19	2.00
Natural Gas Substitution	3.93	0.16	1.51
Nuclear Fuel Substitution	4.21	0.18	1.84
Conservation Emphasis	3.87	0.16	1.47

Note: Emission levels were not calculated for the alternative fuel substitution case.

tons) but also would account for more of the total emissions (78 percent of the 3.93 million tons emitted).

Particulate emissions also would be lower under all of the fuel substitution and conservation scenarios than they would be under the base case. However, again because of the expanded use of SIP units to generate electricity, these emissions would be only slightly lower than under the base case.

Utility nitrogen oxide emissions would not increase as much under the fuel substitution and conservation scenarios as under the base case (see table ES-4) since such emissions rise in proportion to increased generating capacity, and less generating capacity is added under all of the substitution and conservation scenarios than under any of the coal-dominated scenarios.

Although annual and episodic concentrations, crop losses, and emission-related mortality were not examined thoroughly under these fuel substitution and conservation scenarios, a few general observations can be made using the patterns developed under the coal-dominated scenario analyses.

CONCENTRATIONS. Since the magnitude of sulfur dioxide and particulate emission reductions consistently correlates with reductions in annual and episodic sulfur dioxide and particulate concentrations, and since all of the fuel substitution and conservation scenarios would reduce these emissions more than the base case would, concentrations should be lower in 2000 under any of the fuel substitution and conservation scenarios than under the base case. This observation is confirmed by calculations performed for the natural gas substitution case. Under the natural gas case, episodic sulfur dioxide and sulfate concentrations would be 25 and 15.6 percent lower, respectively, in the year 2000 than they would be under the base case in that year. Annual average concentrations would be about the same in 1985 and about 7 percent lower in 2000 than under the base case.

PHYSICAL CROP LOSSES. Similarly, physical crop losses in the year 2000 due to utility sulfur dioxide emissions should be lower under any of the fuel substitution and conservation cases than they would be under the base case. However, even under the base case such crop losses would represent less than 1 percent of the total regional yield.

It is the crop losses due to oxidants that these substitution and conservation scenarios should reduce the most. As will be recalled, increased utility nitrogen oxide emissions under the coal-dominated base case could contribute significantly by the year 2000 to crop losses. Thus, since the fuel substitution and conservation scenarios would result in utility nitrogen oxide emissions significantly or substantially lower than those under the base case, related crop losses also should be significantly to substantially lower under these scenarios.

MORTALITY. Finally, mortality related to air quality should decrease under all of these fuel substitution and conservation scenarios. An analysis of sulfate-related deaths under the natural gas substitution case bears out this observation. Under this case, cumulative sulfate deaths related to ORBES-region electrical generation would be 21 percent lower between 1975 and 2000 than they would be under the base case.

9.2 Economic Impacts Related to Air Quality Impacts

UTILITY COSTS. In terms of the monetary costs to the utilities and to the consumer for the lower emissions, all three of these substitution and conservation scenarios should result in lower cumulative pollution control costs and lower cumulative capital costs to install new coal-fired capacity than would the base case (see figure ES-15). These reductions are the direct result of decreased coal-fired generating capacity under all of these scenarios. However, when the costs of installing nuclear-fueled capacity are added, the nuclear fuel substitution case results in total costs about 10 percent higher than the total costs under the base case. The nuclear substitution case would result in these higher costs because the cost of building a nuclear-fueled plant is approximately 20 percent higher than the cost of building a comparable coal-fired plant.

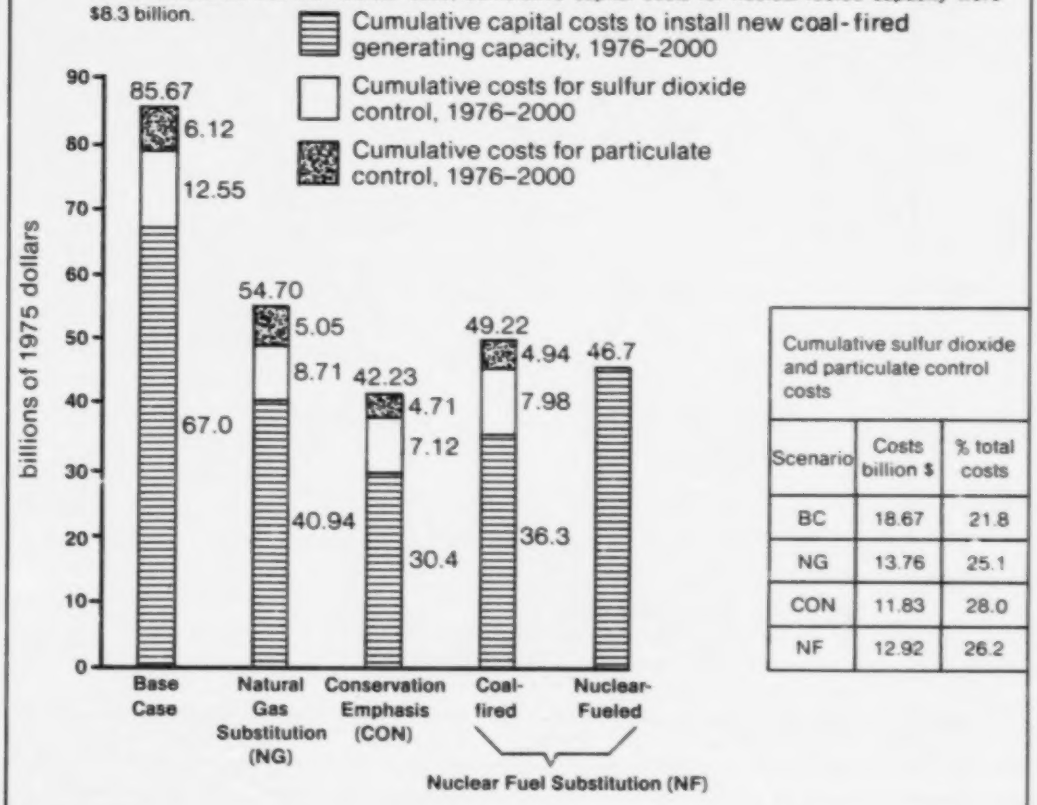
CONSUMER COSTS. Consumer costs were calculated only for the natural gas substitution case. Thus, the exact economic benefits for the consumer of reduced pollution control costs and of reduced capital costs are unknown for the other fuel substitution and conservation scenarios. Under the natural gas substitution case, however, the total revenues collected from consumers between 1976 and 2000 would be lower (by about 26 percent) than the total revenues collected under the base case during the same years. Yet the actual price of electricity in 2000 under the former case would be only 0.2 percent lower in 2000 than it would be under the coal-dominated base case. The reason for this similarity in the year 2000 can be traced to the fact that similar electricity demand growth rates were assumed for these two scenarios between 1985 and 2000.

9.3 Other Impacts Related to Expanded Capacity

HEALTH AND LAND. As a result of decreased generating capacity, decreased coal production, and decreased utility coal consumption under the fuel substitution and conservation scenarios, fewer health impacts related to coal mining, coal processing, and coal transport would occur than would occur under the coal-dominated scenarios. Similarly, land conversion would be lower under these substitution and conservation options than under base case. However, even under the base case, land conversion would represent less than 1 percent of regional acreage, although some state portions would be more affected than others.

Figure ES-15
Cumulative Capital Costs, Base Case, Fuel Substitution Scenarios, and Conservation Emphasis Scenario, 1976–2000

Note: The same nuclear capacity was assumed under all scenarios but the nuclear fuel substitution case. For all scenarios but the nuclear case, cumulative capital costs for nuclear-fueled capacity were $8.3 billion.



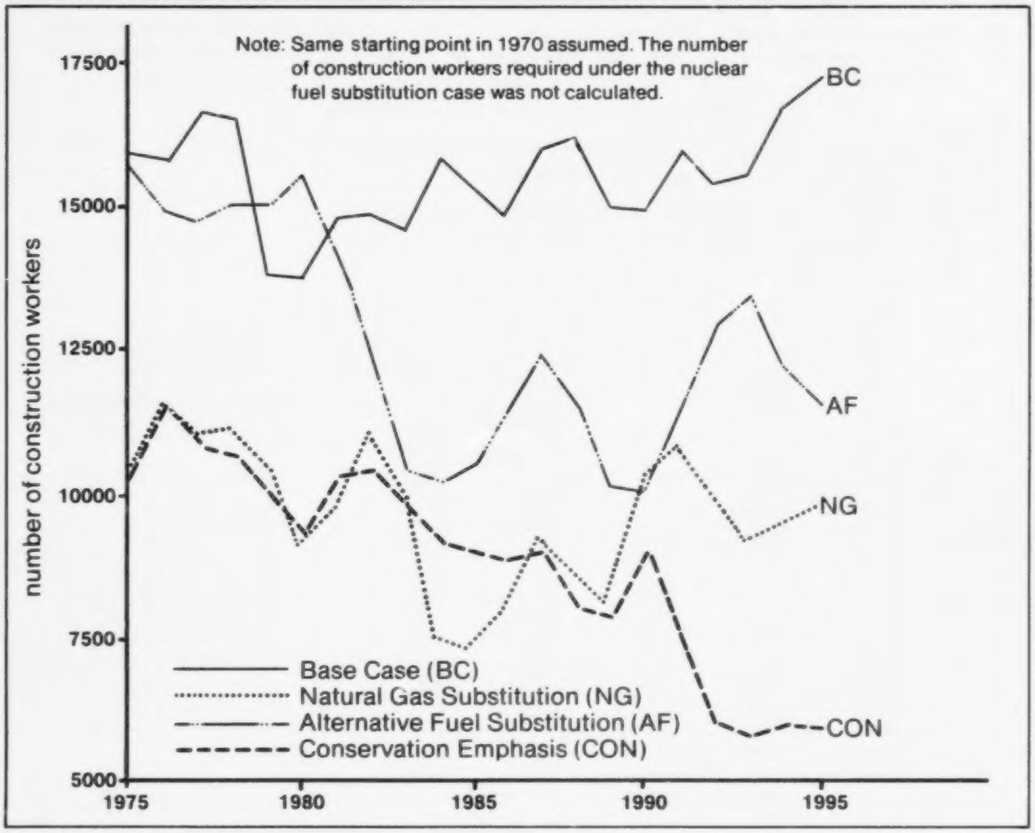
Cumulative sulfur dioxide and particulate control costs

Scenario	Costs billion $	% total costs
BC	18.67	21.8
NG	13.76	25.1
CON	11.83	28.0
NF	12.92	26.2

EMPLOYMENT. Since coal-fired power plant construction and operation would not increase rapidly under the fuel substitution and conservation scenarios, neither would related employment under any of these cases. Compared to the coal-dominated base case, for example, the number of construction and operation workers needed would be much lower (see figure ES-16). However, employment needs related to the increased use of natural gas, nuclear power, or alternative fuels were not calculated; in fact, these needs could compensate for the lower demand for coal-fired power plant workers.

Again because fewer coal-fired generating facilities are sited and because growth is lower in all sectors, less coal would be needed under all of

Figure ES-16
Construction Workers, Base Case, Fuel Substitution Scenarios, and Conservation Emphasis Scenario, 1975–95


Note: Same starting point in 1970 assumed. The number of construction workers required under the nuclear fuel substitution case was not calculated.

the fuel substitution and conservation scenarios than under the coal-dominated cases, although such coal demand would be somewhat higher than at present (see table ES-1). Thus, coal-mining employment for all purposes would increase from current levels at a slower rate under the substitution and conservation scenarios. Moreover, if county-level population increases should exceed the employment increases, negative county-level impacts that might have been avoided under coal-dominated scenarios might be felt under the substitution and conservation cases.

WATER. Regional water quality impacts would be about the same under both the fuel substitution and conservation scenarios and the coal-dominated scenarios. In fact, no changes would be registered in base case protection levels and base case aquatic habitat impacts for any river under any of the fuel substitution and conservation scenarios. This across-the-board similarity, as discussed previously (see sec. 6.3), results primarily from high background concentrations alone or in conjunction with municipal and industrial consumption. In comparison, power plant consumption would have only an incremental impact on most of the streams under all scenarios.

10. INSTITUTIONAL CONSIDERATIONS: NUCLEAR ENERGY, ALTERNATIVE FUELS, AND CONSERVATION

It is considered unlikely that either nuclear energy or alternative fuels will contribute substantially to energy supplies in the ORBES region or the nation, at least by the end of this century. One reason is that a major increase in the proportion of electricity generated by nuclear fuels is not expected to occur in the coal-dominated ORBES region. A second reason is that a major shift to alternative fuels would require more extensive technological and institutional changes than are considered possible in the next 20 years. However, conservation could make significant inroads by the end of the century. Conservation would require improvements in end-use efficiencies and changes in lifestyle, but no radically new technologies. (Existing institutional mechanisms would be adequate to handle a major increase in the use of natural gas.)

NUCLEAR ENERGY. Within the ORBES region, opposition to the use of nuclear energy for electrical generation is particularly visible in Kentucky, Pennsylvania, and West Virginia. Among the factors leading to this opposition are the doctrine of federal preemption, controversy over the health effects of low- and high-level radiation, and growing dissatisfaction with the economics of nuclear energy.

With regard to preemption, the central, unresolved question is whether a state may legally pass legislation to control the placement of nuclear facilities or the transportation or storage of nuclear materials within its borders. With regard to the economics of nuclear-fueled generation, nuclear-fueled units are slightly more expensive to build than are coal-fired units under the current fiscal and regulatory schemes prevalent in the ORBES region. In addition, at least in a representative portion of the region, the cost advantage of coal would be substantially greater without present federal tax and other fiscal policies that favor capital-intensive production (including the nuclear industry).

ALTERNATIVE FUELS. The alternative fuels case considers the partial substitution of direct and indirect solar energy processes for coal-fired electrical generation in the ORBES region.

Solar Energy. Three broad groups of institutional issues are associated with the introduction of solar energy: legal and physical access to sunlight, integration with existing energy infrastructures and institutions, and government program implementation and management.

The solar access barrier stems from the basic orientation of real property law toward the development of land. That is, the potential investor in a solar energy system is not guaranteed permanent access to sunlight. Changes in nuisance law, zoning, solar easements, and restrictive covenants offer possible remedies. At present, limited solar access laws have been enacted in Illinois and Ohio.

The integration of solar energy systems into existing energy infrastructures and systems raises a number of issues, including (1) the rates paid by utilities for power sold to the grid as well as for back-up power and other services provided to on-site generators, (2) the legal status of on-site generators, (3) the financing and ownership of dispersed capacity, and (4) utility management problems and perceived risks. The first two issues are dealt with in part by the Public Utility Regulatory Practices Act of 1978 (PURPA), part of the National Energy Act. The third issue is handled somewhat by the National Energy Conservation Policy Act. For the fourth issue to be dealt with, utility management techniques would have to change to accommodate a transition to dispersed capacity.

Finally, the present management of government solar programs is hampered by a number of deficiencies within the Department of Energy's Conservation and Solar Energy Programs, such as a constantly changing organizational structure.

Wind Energy. As with solar and other dispersed electric energy systems, the widespread introduction of wind energy conversion systems would raise a number of legal and institutional issues. These include financing, siting, tort liability, and environmental problems.

Biomass. Although biomass is a promising energy source for the ORBES region, its use on a wide scale also would entail the solution of unresolved institutional questions. An issue common to all bioenergy sources is the need to develop programs to provide information and technical assistance to bioenergy users. Also needed is the establishment of reliable supply infrastructures for direct energy uses of biomass resources. In both public and private operations, long-range energy and resource planning and proper resource management would have to take place. Institutional changes would be required to link bioenergy to conventional energy supply infrastructures and users. For example, where biomass is used to produce electricity, provisions must be made to sell surplus power to the grid at equitable rates and to supply back-up power to producers of bio-electricity. Finally, federal administration of bioenergy research, development, and implementation would have to be improved.

Each form of biomass entails additional issues. The primary institutional issue associated with the use of wood as energy is the management and care of the resource base, that is, forest lands. The primary institutional issues associated with intensive agricultural production for energy are the integration of energy demand for crops into existing markets and the potential for environmental damage. The use of municipal solid wastes for energy raises institutional issues related to the removal of barriers to resource recovery.

CONSERVATION. Only one conservation measure--cogeneration--was quantified for use in an ORBES scenario. Economic factors are the primary institutional considerations associated with the introduction of cogeneration by industries, notably the rate of return on investment in cogeneration technology. The most important cost consideration is the savings realized from cogeneration when compared with the alternative costs of separate operations for in-house steam production and purchased electricity. Other concerns are effects on the environment and potential regulatory constraints.

11. CONCLUDING NOTE

One important insight gained by the ORBES researchers is that the study region, part of which is known popularly as the Ohio River valley, is far more diverse than they had suspected and probably more so than most public officials realize. Failure to recognize this diversity most certainly will doom to failure any attempt at basinwide institutional innovations. There is indeed balkanization within the ORBES region, and with a continued emphasis on coal, ideological divisions probably will become more pronounced.

The local and long-range transboundary movement of air pollutants across state lines is the single issue within the broad context of continued (and perhaps increased) reliance on coal that could produce the most conflict. Since ORBES began in 1976, this issue has gained increased attention in the region. It affects employment levels in the coal-mining industry as well as in industry in general. It triggers emotions that are easily translated into political controversy.

But many of the ORBES researchers--air pollution experts, economists, lawyers, political scientists, and others--believe that institutional mechanisms can be devised that will permit the region to enjoy the benefits of both reasonably clean air and a degree of economic growth. The creation of such mechanisms will require the highest technological competence, as well as social and political imagination. If there is any single finding of the Ohio River Basin Energy Study, it is that steps toward both clean air and economic growth in the region can be taken only if ways can be found to unite the various factions. Many residents of the region have recognized this reality, but they remain separated by ideology. Some believe that the steps should be initiated by government, while others favor action within the private sector. It is not the responsibility of ORBES researchers to recommend which path should be followed. But it is our responsibility to warn that inaction could result in economic stagnation and accompanying social problems capable of draining much-needed vitality from the region and from the nation at-large.

Main Report

INTRODUCTION

1. ORBES Background and Organization

The Ohio River Basin Energy Study (ORBES) began in the fall of 1976 in order to assess the potential environmental, social, and economic impacts of a proposed concentration of power plants in a portion of the basin. At that time, the U.S. Environmental Protection Agency (EPA) awarded grants to faculty members from a group of universities in the basin states of Illinois, Indiana, Ohio, and Kentucky. As the investigation progressed, researchers from universities in Pennsylvania and West Virginia were added to the study group. Experts from outside the academic community also took part throughout the project.

In 1975, the U.S. Senate Appropriations Committee had directed EPA to carry out such a study. It was not long after the Arab oil embargo (1973-74), and a number of electric utilities had announced plans to construct additional generating units in the Ohio River Basin and in nearby areas that share its fuel supply. The Ohio River region offers electric utilities and related industries some of the nation's most suitable sites. Coalfields that contain almost half the tonnage of national reserves are within easy reach. Adequate water for cooling also is available in the area, and regional waterways provide good fuel transportation routes. Finally, in sparsely populated areas of the basin, large generating facilities can be constructed without displacing as many residents as they would in urban areas.

In the fall of 1974, publicity was given to plans by electric utility companies to locate coal-fired plants on a 100-mile reach of the Ohio River from Louisville, Kentucky, northward and eastward to Cincinnati, Ohio, and beyond. Utility planners and observers from related industries, such as coal producers, viewed the plans as consistent with emerging national energy policies for dealing with increased fuel prices and with such external disruption of the fuel supply as had just been experienced during the oil embargo. From the perspective of these sectors and others, the expansion of the nation's coal-fired capacity is essential if the U.S. standard of living and quality of life are to be maintained. Citing such examples as the high production efficiency that is dependent on energy-intensive machines and the air conditioning that is vital to the elderly, they state that continuation of the present national standard of living and quality of life is tied to the availability of energy.

In contrast to this view, some citizens in the Ohio River region became increasingly concerned about the effects of the announced units and questioned the necessity for such expansion. In late 1974, Public Service Indiana announced that it would build a nuclear-fueled facility, the Marble Hill plant, on the Ohio River between Louisville and Cincinnati. Citizen concern intensified. Over the six years since this plant, now under construction, was announced, controversy has grown. Citizens opposing this and other proposals have questioned the necessity of adding such a large number of generating facilities on the Ohio River itself, which already contains almost 40 percent of the capacity in the six states that border the river--Illinois, Indiana, Kentucky, Ohio, Pennsylvania, and West Virginia. Opponents have pointed out that the proposed new plants would transmit much of their electricity far from the immediate area.

In an effort to identify the implications of locating future energy conversion facilities in this particular part of the Ohio River Basin, the Senate Appropriations Committee directed EPA to conduct a study, "comprehensive in scope, investigating the impacts from air, water, and solid residues on the natural environment and [on the] residents of the region. The study should also take into account the availability of coal and other energy sources in this region."[1]

The region investigated in this report is somewhat different from that studied when the project first got underway. The Senate committee had called for a study of "the proposed concentration of power plants along the Ohio River in Ohio, Kentucky, Indiana, and Illinois." Phase I of the Ohio River Basin Energy Study focused on portions of these four states. Findings were integrated in a summary publication.[2]

Although the present report expands on the findings of Phase I, it deals primarily with the second phase of the project. Phase I researchers were aware that a study of the "lower Ohio River Basin" in the four states noted in the Senate committee report meant an emphasis on the Eastern Interior Coal Province, approximately located in western and southern Illinois, southern Indiana, and western Kentucky. Thus, the boundaries of the ORBES Phase I study region extended northward and westward beyond the Ohio River Basin to include most of the province. Excluded was the northern tier of industrial counties in Illinois, Indiana, and Ohio. The region covered approximately 152,000 square miles, including some coal-laden land actually outside the drainage basin. Because only a small portion of the Appalachian Coal Province was included in the Phase I region, utility leaders, state and federal government officials, and university researchers objected to the boundaries. They felt that the study region should be extended to the headwaters of the Ohio River. Thus, at the beginning of the second phase of ORBES, the region was expanded by about 38,000 square miles to include the southwestern portion of Pennsylvania and virtually all of West Virginia (see figure 1-1). The relationship of the Phase II region to the Eastern Interior and Appalachian coal provinces is shown in figure 1-2.

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[1] The mandate appears in U.S. Congress, Appropriations Committee, 94th Congress, 1st Session, Senate, Department of Housing and Urban Development-Independent Agencies (Senate Report 940326, 1975).

[2] See James J. Stukel and Boyd R. Keenan, ORBES Phase I: Interim Findings. Citations to all ORBES reports appear in Appendix B.

ORBES Phase II began in the fall of 1977; active research concluded in early 1980. As in Phase I, the project management team included the EPA project officer, other officials of the agency, and two of the university researchers. These two faculty members coordinated the activities of a core team of researchers (on which they also served), the project advisory committee, and support researchers. See Appendix A for rosters of each of these groups.

Figure 1-1
Ohio River Basin Energy Study (ORBES) Region

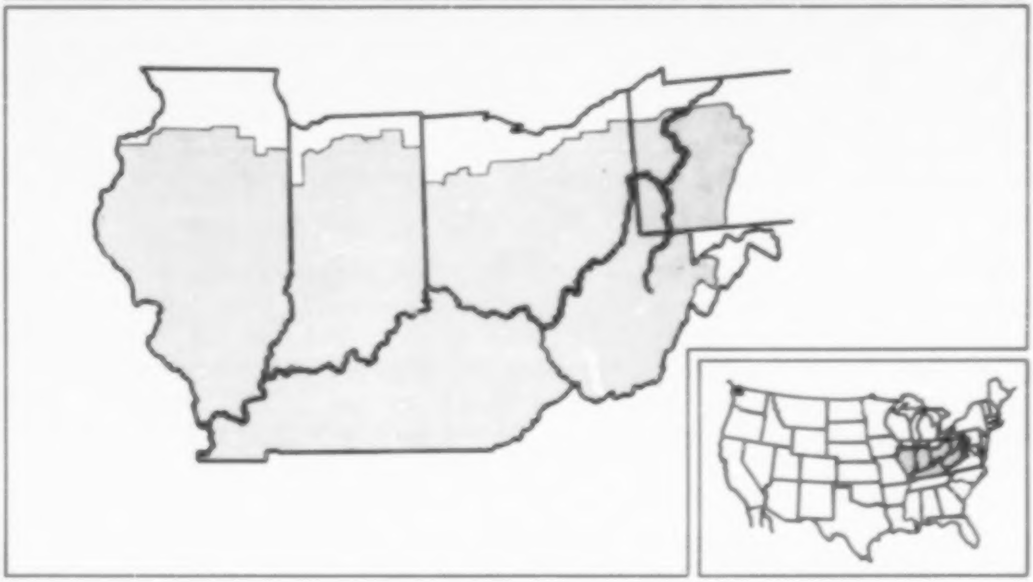
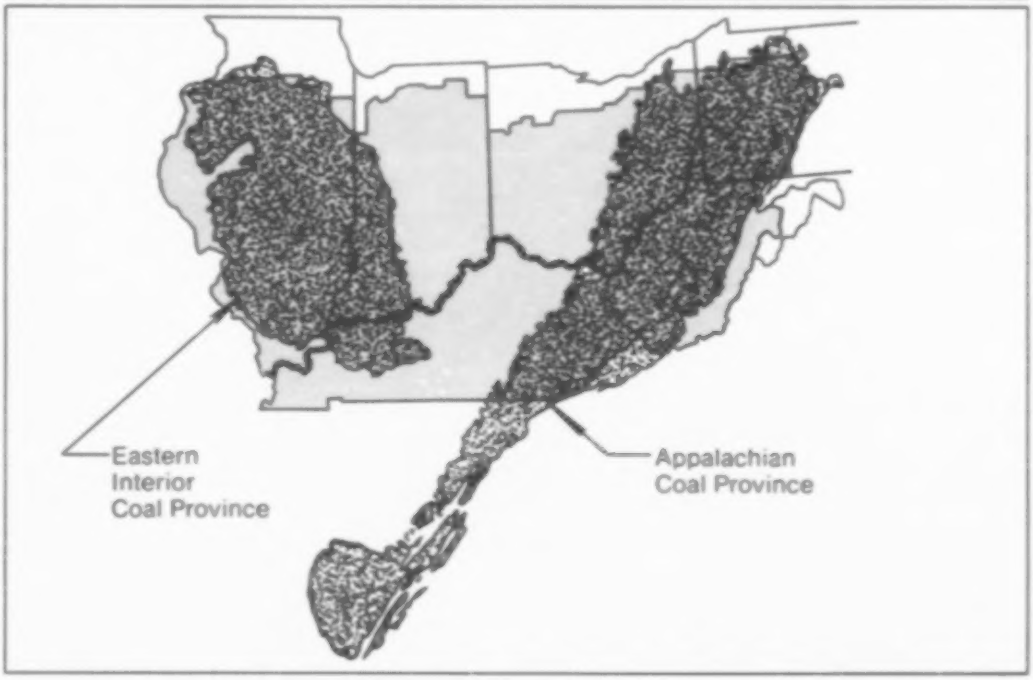


Figure 1-2
ORBES-Region Coalfields


Eastern
Interior
Coal Province
Appalachian
Coal Province

2. Policy Issues

In accordance with its congressional mandate, the Ohio River Basin Energy Study identified a number of environmental, economic, and social issues associated with increased coal-fired electrical generation in the region of concern. All of these issues relate to the policy assumptions made during the study, which are discussed in chapter 3 in the context of the overall approach to the ORBES assessment. The present chapter deals with the major policy issues and the major energy and environmental laws considered in the study.[1]

2.1 Air-Related Policy Issues

Air quality is of major importance in the ORBES region because of the regional emphasis on coal-fired electrical generation. The key air quality issue is the local and regional effects of changes in pollutant concentrations as a result of different levels of electric generation and different control technologies.

Related directly to the key air quality issue are such factors as emission limitations, generating unit retirement schedules, and other factors, as well as a variety of economic and social issues. These social and economic issues include the cost of electricity to the consumer, capital costs for pollution control devices, mortality related to air pollution, and losses in agricultural output as the result of air pollution.

CLEAN AIR ACT. The first federal legislation concerned with air quality was the Air Pollution Control Act of 1955. At present, the governing federal law is the Clean Air Act (42 U.S.C. 1857 et seq.), a sweeping national approach to the control of air pollution. The act is implemented by the U.S.

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[1] It is recognized, of course, that a variety of other issues and laws are of present or potential importance in the ORBES region. Among these statutes are the National Environmental Policy Act (42 U.S.C. 4321 et seq.), the Resource Conservation and Recovery Act of 1976 (42 U.S.C. 6901 et seq.), the Energy Supply and Environmental Coordination Act (P.L. 93-319 as amended by P.L. 94-163 and P.L. 95-70), and the Powerplant and Industrial Fuel Use Act of 1978 (P.L. 95-620).

Environmental Protection Agency in cooperation with the states. Passed in 1963, the Clean Air Act has been strengthened considerably by a series of amendments, particularly those passed in 1970 and 1977.

The fundamental concept behind the 1970 and 1977 amendments is that the federal government has the responsibility (assigned in the amendments to EPA) to set national ambient air quality standards (NAAQS) as well as standards for the control of emissions from new sources of pollution. These standards set limits for concentrations in the ambient air (free-flowing air outside buildings) of certain air pollutants, known as criteria pollutants. These concentration limits are stated in parts per million or micrograms per cubic meter.

In partnership with EPA, each state is to develop a specific strategy to ensure that federal standards will be achieved in all areas of the state. These strategies are known as state implementation plans (SIPs). If a state does not develop an implementation plan, EPA will develop a plan for achieving the standards within that state. Each SIP must contain emission limitations for each major emission source in the state, set either on a case-by-case basis or by source category. SIPs also must ensure that full compliance with NAAQS must be achieved by 1982, with some exceptions made for two criteria pollutants. As of September 1980, EPA had approved all sections of the state implementation plans developed by two of the six ORBES states--Illinois and Indiana.

At present, EPA has set NAAQS for seven criteria pollutants: total suspended particulates, sulfur dioxide, oxides of nitrogen (expressed as nitrogen dioxide), hydrocarbons, photochemical oxidants, carbon monoxide, and lead. Significant amounts of sulfur dioxide and nitrogen dioxide, as well as an appreciable fraction of fine particulates, are emitted by coal-fired plants and other coal-fired industrial sources. The four other criteria pollutants are primarily products of transportation. Other potentially harmful compounds that are not regulated nationally are formed through chemical transformation of criteria pollutants. For example, sulfates are formed by the transformation of sulfur dioxide.

Each criteria pollutant must meet two types of standards: primary standards, which are intended to protect human health, and secondary standards, which are intended to protect the public welfare (defined as including property, soil, vegetation, scenic value, and other effects not related directly to human health). Depending on the pollutant, these two types of standards are broken down further into annual average, 1-hour, 3-hour, 8-hour, and/or 24-hour concentrations. EPA standards for 1-hour, 3-hour, 8-hour, or 24-hour concentrations of criteria pollutants in the ambient air may not legally be exceeded more than once a year at any one location.

New stationary sources of pollution are required to meet emission standards set for a number of individual source categories--such as those set for the fossil-fueled power plant category--based on when their construction began. These standards are known as new source performance standards (NSPS). In the fossil-fueled power plant category, NSPS apply to sources on which construction began between 1971 and 1978 and are designed to limit the emissions from each new plant according to the type of activity and the size of the plant. Standards stricter than the NSPS apply to sources under construction after August 1978. In this report, these standards are referred to as revised new source performance standards (RNSPS).

To aid the states in developing and carrying out the SIPs, EPA has formally designated attainment and nonattainment areas according to whether or not these areas meet primary and/or secondary standards. Within nonattainment areas, emission offset provisions are in effect. This means that a new source cannot be built unless it obtains from existing sources in the area an emission reduction that is equal to or greater than its own expected emissions. Thus, over time, attainment status will be achieved and air quality in the area will improve. If violations of a state implementation plan are widespread, EPA can enforce any SIP requirement by issuing an order to comply, bringing a civil action, and/or prohibiting the construction or modification of a major stationary source of pollution in the area.

The original design of the Clean Air Act provided that all areas of the country would have the same NAAQS. However, this design permitted pollutant emissions to increase considerably in areas with very clean air. Judicial interpretation and the 1977 amendments changed this design. Prevention of significant deterioration (PSD) requirements now are prescribed. Under the PSD requirements, new facilities in areas where air quality is above that specified by NAAQs are subject to extensive preconstruction review and permit requirements, including maximum allowable increases, or increments, in ambient concentrations of pollutants from those facilities. Special protection is to be given to visibility near selected federal lands, such as national parks, but this provision is not yet implemented fully.

2.2 Land-Related Policy Issues

Land is another environmental receptor that raises issues in the ORBES assessment. These include land displacement for energy-related uses, the effects of air pollutants on plant species, and the effects of energy facilities on terrestrial ecosystems.

SURFACE MINING ACT. The Surface Mining Control and Reclamation Act (30 U.S.C. 1201), passed in 1977 and administered by the Department of the Interior, is the major federal law that governs coal surface mining. This act is based on the premise that surface mining is only a temporary use of the land and that other beneficial uses should follow. The law is intended to change coal-mining practices that entail severe social and environmental costs and to prohibit mining operations in areas that cannot be reclaimed. However, because of revisions to the regulations promulgated under the law since its enactment, as well as because of continuing litigation over certain aspects of the act, the final way in which this legislation will be enforced is unclear.

In accordance with the act, state permits for new coal mines must include comprehensive performance standards for surface mining operations and for the surface effects of underground mining. These standards are intended to prevent adverse effects on the environment, such as subsidence, ground and surface water contamination, and degradation of land quality. Thus, before a permit can be obtained, the mining operator must demonstrate that the land can be restored to a postmining land use that is the same as or of higher quality than its premining use. Until these state permit programs are in force, or in the event of a state's failure to establish an adequate program, the federal government retains regulatory authority.

Also in accordance with the surface mining act, states must institute a planning process for the designation of areas unsuitable for all or certain types of surface mining. Among such areas are those where reclamation would not be technically or economically feasible; where it would not be compatible with existing land use plans; where it would adversely affect important historic, cultural, scientific, or aesthetic values; where it would result in substantial loss of or reduction in long-range productivity of water supplies or food or fiber products; and where it would endanger life or property in areas subject to flooding or unstable geology.

Finally, the act establishes a fund for the reclamation of abandoned mines and prohibits surface mining on federal land valuable for recreation or for other purposes, such as national forests, except for valid existing rights.

2.3 Water-Related Policy Issues

Because of the amount of water required from streams to cool power plant boilers, this environmental medium also is of primary importance to the ORBES assessment. The key policy issues are the availability of water, water consumption by electrical generating facilities, the effects of consumption on effluent concentrations (which increase as the quantity of water decreases), and the effects of effluent concentrations on aquatic habitats.

CLEAN WATER ACT. The Clean Water Act (33 U.S.C. 125) contains numerous provisions that apply to the use of water for the extraction of fossil fuels and the generation of electricity. The 1972 amendments to the act continued the existing requirement that states establish water quality standards for their interstate waters and broadened this requirement to include intrastate waters. Each state must classify the desirable uses of its waters and define the pollutant concentrations that may not be exceeded in order for these desirable uses to continue without hindrance.

The National Pollution Discharge Elimination System (NPDES) is the means for ensuring that individual dischargers comply with effluent limitations set under the Clean Water Act. Every facility that discharges effluents into navigable waters must receive a permit that specifies the minimum effluent requirements. EPA may delegate the authority to issue these permits to the states, although it retains the authority to review permits. As of March 1980, the ORBES states of Illinois, Indiana, Ohio, and Pennsylvania were responsible for administering their programs, while permits still were issued by EPA in Kentucky and West Virginia. These individual source permits specify effluent limitations by pollutant, derived from the limitations established by EPA or from classifications of desirable use established by the state, whichever is more stringent. However, stricter limitations can be imposed if they are necessary to achieve a state's water quality standards.

The 1972 amendments set forth water pollution control standards to be met by all effluent dischargers by 1977. In addition, the amendments established more stringent standards, to be met by 1983. Both sets of standards included a combination of water quality standards and technology standards. The technology standards required that, by 1977, every discharger install equipment representing the best practicable control technology. By 1983, dischargers were required to install additional equipment representing the best available technology that is economically achievable. Additional amendments in 1977 changed the requirements for 1983. First, the deadline was postponed until July 1984. Second, the best available technology requirement was replaced with a more complicated formula. The best conventional technology (stricter than the best available technology) is required for certain conventional pollutants. The best available technology is required for toxic pollutants. The best available technology also is required for certain other pollutants (subject to possible extension of the deadline to July 1987).

2.4 Social Policy Issues

The public and occupational health consequences of energy development, as well as the employment requirements associated with energy facilities, are major social policy issues. These include death, disease, and disability related to coal conversion and nuclear generation; occupational death, disease, and disability from the mining, processing, and transportation of fuels; and labor demand for coal mining and for power plant construction and operation.

MINE HEALTH AND SAFETY ACT. The most recent expression of congressional intent to remedy unsafe working conditions and practices in mines and thereby reduce the number of mining fatalities and injuries is the Federal Mine Health and Safety Act (30 U.S.C. 801), enacted in 1977. This act is based on the 1969 Federal Coal Mine Health and Safety Act. The 1977 act incorporates many of the provisions of the 1969 act--such as those that deal with mandatory health and safety standards and with black lung benefits--but increases the level of protection for miners. Under the 1977 act, standard-setting and enforcement procedures are made uniform throughout the mining industry, while the standards themselves reflect the characteristics of different segments of the industry. Each step in the standard-setting and revision process requires compliance within a specific period, and enforcement timetables are more rigorous than in previous legislation. Provisions also are made for training courses for new miners and refresher courses for experienced ones. During these courses, workers receive their normal rates of pay and are compensated for any costs incurred while attending the training.

The Department of Labor administers the law. The Federal Mine Safety and Health Review Commission, an independent adjucticatory authority, provides due process. Affected miners or their representatives can participate in the commission's proceedings.

2.5 Other Policy Issues

A secondary set of issues considered in the ORBES assessment concerns a possible decrease in coal use due to the partial replacement of coal by other fuels or by conservation measures. One substitution fuel is natural gas, not as a utility boiler fuel, but as a replacement for electricity in other sectors. Nuclear fuel constitutes a direct substitution for coal in the generation of electricity. Alternative sources of energy, such as biomass, solar energy, and wind, also could lower the demand for coal-fired generation. Finally, conservation could decrease the demand for all fuels, including coal.

The orientation of the ORBES region to coal for electrical generation is unlikely to change significantly within the next 20 years.[2] Toward the year 2000 and beyond, however, fuel substitutions could begin to decrease the regional coal emphasis, although significant change is considered unlikely by many. On the other hand, conservation could make major inroads before the end of the century, although a variety of institutional problems exist. Therefore, the emphasis in the examination of the fuel substitution and conservation scenarios is on the institutional barriers to their implementation.

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[2] It is extremely likely that synthetic fuels made from coal will become increasingly important in the ORBES region. However, a full-fledged synthetic fuel industry probably could not be in place within the next 20 years, which is the time frame of the ORBES study. Thus, synthetic fuels were not considered in the analysis.

2.6 Underlying Methodological Issues

It is recognized that the choice of policy issues, and indeed the ORBES study as a whole, could be affected by methodological fallacies.[3] Such fallacies are common in research, which is one activity among many social decisionmaking processes.

Three possible methodological fallacies are termed the appeal to the people, also called the fallacy of consensus; the appeal to authority; and the argument from ignorance, or proceeding without all the facts. Ideally, the selection of a policy issue or of any research direction should be valid either because of empirical evidence or the logical inferences on which it is based. It should not be considered valid because of the number or authority of those who support it. The opinion of the majority may be wrong, and consensus is logically irrelevant to the truth of the statement in question. The conclusions of authorities in a given field also may be wrong, and these conclusions should be checked by the replication of data.

The most troublesome methodological problem, but an unavoidable one, is the argument from ignorance. The choice of a policy issue should not be considered valid because it is assumed so until proven otherwise. Several examples illustrate this problem in the case of ORBES. First, the impacts of nuclear-fueled electrical generating units are evaluated without knowledge of the health effects of low-level radiation. Similarly, the effects of such radiation from the burning of coal are unknown. On the other hand, the health benefits from electricity--such as its use for life support systems and air conditioning--are not entirely clear. Moreover, the contribution of coal-generated carbon dioxide emissions to concentrations of this pollutant in the atmosphere is not understood. The argument from ignorance also is committed when high electrical energy growth rates are projected without information on whether there is need for the electricity that would be generated by increased numbers of power plants. Nor is there information about what would occur if this electricity were not generated. In addition, whether utility expansion contributes to overall economic growth is unknown. Finally, without adequate information on the need for additional plants, decisions on the taking of land by means of eminent domain are made in ignorance. Also unknown are the effects on society as a whole if sites for power plants could not be acquired through eminent domain and if these plants were not built.

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[3] For discussion, see Preliminary Technology Assessment Report, vol. II-B (ORBES Phase I).

It is acknowledged that during the course of ORBES many judgments were made based on inadequate data. This problem was inescapable, as it is in any research exercise, or indeed any decisionmaking process.

3. Assessment Approach and Report Organization

3.1 Assessment Approach

The approach taken in the Ohio River Basin Energy Study was that of a technology assessment. The objective was to analyze a broad range of environmental, social, economic, and institutional effects associated with possible energy development in the study region. The primary focus was on the consequences of coal use within the region for the generation of electricity. This focus reflects both the congressional mandate for the study and existing fuel use patterns (see section 4.1).

A variety of scenarios, all regionally based, are presented and analyzed in this report. Each scenario is an "as if" statement that does not predict what will occur. Rather, a scenario represents what one future might be like if assumed conditions are present in the ORBES region. As mentioned above, the analysis emphasizes those scenarios in which the continued use of coal in the region through the year 2000 is assumed. However, there are a number of variations in the paths entailing coal emphasis, such as the degree of strictness of environmental regulations and the rate of electrical energy growth. Whatever the distinguishing feature of a scenario, the scenario is cast in terms of the study region, not the United States as a whole or the six ORBES states.

It also is important to note that the impacts of the various scenarios are not intended to form the basis for regulatory action. Rather, these impacts are discussed in terms of their overall policy implications. Even though severe local problems might exist under a given scenario, the analysis emphasizes impacts on a regionwide basis. Thus, the study results cannot be applied directly to such activities as the writing of environmental impact statements, which focus on specific sites.

Only potentially important impacts, both positive and negative, are described in this report. Judgments were made in the course of the research as to which impacts were worthy of analysis and presentation, and thus the detail in which impacts are presented varies among scenarios. Moreover, the study results are not presented with the same exactitude as they would be in a scientific journal; the intent is to inform policymakers of the possible consequences of a range of hypothetical futures.[1] In addition, the analysis emphasizes extreme, but possible, natural conditions--for example, 7-day-10-year low flow conditions and adverse meteorological conditions. The impacts identified for each scenario are divided into the issue areas discussed in chapter 2: air and associated economic questions; land and associated economic questions; water; employment; and health.

In order to develop the scenarios, it was necessary to delineate base period conditions in the ORBES region. In general, the base period is the mid-1970s.[2] The scenarios then were developed by means of a regional energy and fuel demand model. This model can take into account alternative policy specifications for future conditions, such as interfuel substitution and technological change. Among the outputs of the model are the regional energy and fuel use requirements by end user that are associated with various levels of economic activity.[3] These requirements are necessary information for application of a model to site central station coal-fired and nuclear-fueled electrical generating unit additions in the study region from 1976 through 2000.[4]

Figure 3-1 depicts regional electrical generating capacity as of December 31, 1976. Units announced by the electrical utilities, both coal fired and nuclear fueled, were assumed to come on-line as scheduled through the mid-1980s. For each scenario, "standard" units were projected--650 megawatts electric for each coal-fired unit, operating at a 50 percent capacity factor, and 1000 megawatts electric for each nuclear-fueled unit, operating at a 65 percent capacity factor. However, nuclear-fueled units beyond those scheduled were sited in only one scenario (see chapter 13).

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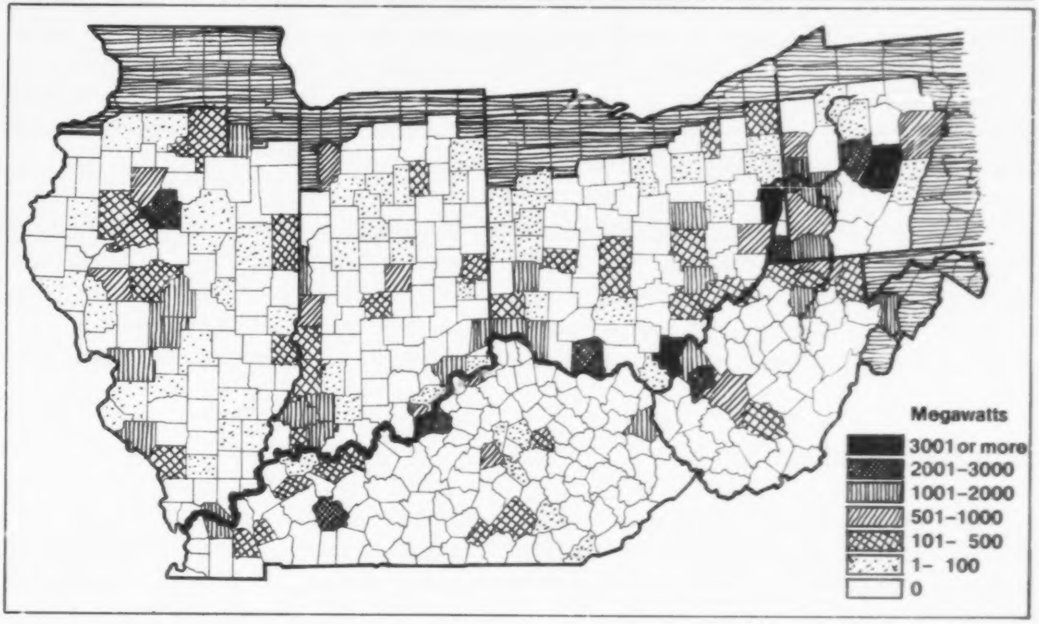
[1] Throughout this report, references to the more specialized documents in the ORBES series are only by author and title. These other reports should be consulted for documentation of results.

[2] Because of the large number of researchers in different disciplines, it was not possible to investigate all base period conditions in terms of a single year; the best data bases available varied among disciplines. However, the conditions of most interest are projected to the year 2000.

[3] See Walter P. Page, Doug Gilmore, and Geoffrey Hewings, An Energy and Fuel Demand Model for the Ohio River Basin Energy Study Region (ORBES Phase II).

[4] See Gary L. Fowler et al., The Ohio River Basin Energy Facility Siting Model: Methodology (vol. I) (ORBES Phase II).

Figure 3-1
Electrical Generating Capacity,
ORBES Region, 1976



The necessary number of standard units were sited to meet the final energy demand projected for each scenario by the energy and fuel demand model. The siting model was used to locate these units at the county level, in accordance with scenario policies in selected impact or issue areas. A generating unit lifetime of 35 years was assumed for all but one scenario.[5]

Nine scenarios are presented and analyzed in this report; their major policy variables are discussed in chapter 5, which describes the coal-dominated scenarios, and chapter 13, which describes the fuel substitution and conservation scenarios. Impacts are presented in detail for those scenarios that call for the continued use of coal in the region through the year 2000 (chapters 6 through 11). Impacts of the remaining cases are examined in less detail (chapter 14).

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[5] See Gary L. Fowler et al., The Ohio River Basin Energy Facility Siting Model: Sites and On-Line Dates (vol. II) (ORBES Phase II).

Among the five coal-dominated futures, the conditions emphasized consist of, respectively, (1) "base case" environmental regulatory policies, fuel use patterns, and economic and energy growth rates in the ORBES region, (2) more stringent environmental regulations, (3) less stringent environmental regulations, (4) high electrical energy growth, and (5) exports of electricity from the ORBES region. The scenarios calling for partial coal substitution emphasize (1) the use of natural gas wherever possible, although not as a fuel for the generation of electricity, (2) the use of nuclear fuel, and (3) the use of less conventional energy sources. The final scenario assumes a regional emphasis on energy conservation, which also would lessen the demand for all fuels, including coal.[6]

Impacts of the coal-dominated base case in the year 2000 are compared with current conditions in the ORBES region (that is, the mid-1970s). In general, impacts of the other cases are contrasted with those of the base case and with each other, not with conditions during the base period. Certain special cases, variations of the major scenarios, also are discussed.

3.2 Report Organization

The substantive chapters in this report contain a description of base period conditions in the ORBES region, presentations of the various scenarios and their impacts in 1985 and 2000, and discussions of policy considerations associated with the scenarios. In chapter 4, base period regional conditions are delineated in eight areas, primarily as they relate to the production and use of electrical energy in the region. The topics covered are regional energy and fuel use patterns (section 4.1), the regional economy (section 4.2), air quality (section 4.3), water quantity, water quality, and aquatic ecology (section 4.4), land use and terrestrial ecology (section 4.5), public and occupational health (section 4.6), social conditions in the region (section 4.7), and social values (section 4.8). The presentation of current conditions serves as an introduction to consideration of the scenarios (chapters 5 and 13) and of the impacts that would result from each scenario future (chapters 6, 7, 8, 9, 10, 11, and 14).

Chapter 5 describes the five scenarios that emphasize regional coal use for the generation of electricity. Two basic parameters, environmental regulations and regional electrical energy growth, are varied. In chapter 6, the impacts are contrasted across scenarios in terms of air, land, water, employment, and health. Economic impacts associated with air and land are discussed in these topical areas. Impacts by scenario then are treated in chapters 7 through 11.

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[6] Alternative designations for the various scenarios as used in other ORBES reports appear in Appendix C.

The first of these coal-dominated futures, discussed in detail in chapter 7, is termed the base case. As the starting point for the other scenarios, it is the most fully analyzed future. In terms of environmental regulatory policies, the regional economy, and regional energy and fuel use, the base case is comparable to conditions in the ORBES region during the base period. Therefore, the impacts in the various areas that would arise under base case conditions in 1985 and 2000 are compared with base period conditions.

In chapter 8, the focus is on stricter environmental regulatory policies than those of the base case. The scenario presented assumes that stricter air, water, and land quality regulations will be in effect in the ORBES region, while the moderate regional electricity demand growth and the coal emphasis of base case conditions are maintained. Future impacts of the strict environmental control case are contrasted with those of the base case.

In chapter 9, the policy examined is noncompliance with state implementation plans (SIPs) for achieving clean air standards (see chapter 2) along with a continued regional emphasis on the use of coal for electrical generation. Impacts of the SIP noncompliance case, chiefly on air quality, are contrasted with those of the base case.

In chapter 10, the effects of higher electrical energy growth than that of the base case are considered. The emphasis again is on coal-fired electrical generation. A high rate of regional electrical energy growth and a 45-year generating unit lifetime are assumed. (In all other cases, a plant lifetime of 35 years is assumed.) The high electrical energy growth rate is based on projections of the National Electric Reliability Council (NERC). Two variations also are presented. In the first, a 35-year generating unit life is assumed under the same conditions of high electrical energy growth. In the second, a policy of least sulfur dioxide emissions dispatch is assumed. That is, the criterion for the order in which a generating unit comes on-line, or is dispatched, is on the basis of the unit's expected emissions of sulfur dioxide. In all other scenarios, the dispatching order is on the basis of least cost--the usual utility practice.

The final coal-dominated scenario examined, in chapter 11, concerns a major increase in the "export" of coal-generated electricity from the ORBES region to the Northeast. Aside from the siting of an additional 20,000 megawatts of electrical generating capacity to be transmitted outside the region, all conditions are identical to those of the base case.

As became clear from the analysis, the major policy implications of the coal-based futures relate to regional air quality issues. Strategies to mitigate adverse impacts on air quality from electrical generating facilities are discussed in chapter 12.

In chapters 13 and 14, the focus is on partial regional substitution for coal by other fuels, as well as on energy conservation. The four scenarios considered are described in chapter 13; their impacts are compared in chapter 14. The emphasis, however, is the institutional barriers and opportunities associated with the implementation of these alternatives to coal; these barriers and opportunities are the subject of chapter 15.

Finally, a concluding note presents the diverse perspectives in the ORBES region and the relationship of these perspectives to regional economic and environmental problems.

4. Base Period Conditions in the ORBES Region

In this chapter, base period conditions in the Ohio River Basin Energy Study (ORBES) region are delineated in eight areas: energy and fuel use (section 4.1), the economy (section 4.2), air (section 4.3), land (section 4.4), water (section 4.5), health (section 4.6), social conditions (section 4.7), and social values (section 4.8). In general, the base period is the mid-1970s. However, the years reported vary according to the availability and quality of data. Base period conditions are presented primarily as they relate to the production and use of electrical energy in the study region.

4.1 Energy and Fuel Use

COAL. Coal is both widely abundant and widely used in the ORBES region. It is the only significant indigenous fuel in the region, and the region contains a major portion of the nation's coal reserves. Coal is also the primary fuel used within the region; the electric utility industry accounts for over two-thirds of the regional coal consumption.

As noted in chapter 1, there are two extensive coal provinces in the ORBES region. The Appalachian Province extends from western Pennsylvania and eastern Ohio southwestward through West Virginia and eastern Kentucky into Alabama. The Eastern Interior Province is located in Illinois, western Indiana, and western Kentucky (see figure 1-2). These provinces have been further divided by the U.S. Bureau of Mines (BOM). Seven BOM districts are in the ORBES portion of the Appalachian Province and three BOM districts are in the Eastern Interior Province, all of which is in the ORBES region.

The ORBES region contains an immense coal reserve base--193 billion tons, or 45 percent of the national total by tonnage, and probably a majority on the basis of heat value (Btu's). This coal represents 55 percent of the national reserves recoverable by underground mining and 23 percent of the national reserves recoverable by surface mining.[1]

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[1] For more detailed information on the regional coal-mining industry, consult David S. Walls et al., A Baseline Assessment of Coal Industry Structure in the Ohio River Basin Energy Study Region (ORBES Phase II), and

Great variability exists in the type of coal mined in the Eastern Interior and Appalachian provinces. In general, the coal mined in the Eastern Interior Province has a high sulfur content, while the Appalachian coal of eastern Kentucky and southern West Virginia is low in sulfur. The northwestern Appalachian coal of Ohio and northern West Virginia has a sulfur content similar to that found in the Eastern Interior Province. The sulfur content of most Pennsylvania coal is between that of the Eastern Interior and that of the southern Appalachian coals. Similarly, the moisture and the ash content of Eastern Interior coals tend to be higher than those of Appalachian coals, and the Btu content tends to be lower.

In 1970, the ORBES portion of the Appalachian Province provided 65.3 percent of the total coal consumed in the ORBES region, while the Eastern Interior Province supplied 34.2 percent. However, from 1970 to the present, there has been a decline in the percentage of U.S. coal production supplied by these two provinces. This decline is attributable to expanded production in the West and to more stringent environmental controls. Among the ORBES state portions, coal production has fallen most markedly in West Virginia, due primarily to declining markets for metallurgical coal and to labor disputes. It also should be noted, however, that coal markets are highly competitive within the Eastern Interior and Appalachian Provinces.

Until 1974, U.S. underground mines produced more coal than did surface mines. Since that year the opposite has been true. In the ORBES region, however, underground mines still produce more coal, although the proportion produced by surface mines is increasing. In the ORBES region in 1965, approximately 30 percent of the active mines were surface mines; by 1975, this figure had risen to 63 percent. In terms of numbers of mines, Kentucky, especially the eastern part of the state, contributed most heavily to the increase in surface-mining operations. However, despite a 90 percent increase between 1965 and 1975 in the number of ORBES-region surface mines, the percentage of production from these mines rose only 13 percent. The reason is that many of the new surface mines are relatively small operations. Both the number of regional surface mines and the amount of regional and national coal production could be reduced by the implementation of the Surface Mining Control and Reclamation Act of 1977 (see section 2.2).

As part of the ORBES project, deep mine costs were estimated and coals were distinguished on the basis of sulfur categories that are assumed to reflect low- and high-sulfur coals that might be used by existing SIP plants

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Donald A. Blome, Coal Mine Siting for the Ohio River Basin Energy Study (ORBES Phase II). For a discussion of regional energy and fuel use, see Walter P. Page, Energy Consumption in the Ohio River Basin Energy Study Region, 1974, by End User and Fuel Type (ORBES Phase II).

and by NSPS and RNSPS plants. A low-sulfur coal is defined as having 1.8 percent or less sulfur, and a high-sulfur coal as having more than 1.8 percent. In that context, economically recoverable reserves from deep mining vary widely within the regional BOM districts. For example, one BOM district in the Appalachian Province has 88.6 percent of its deep mine reserves in the economically recoverable low-sulfur category, compared with no such reserves in a BOM district in the Eastern Interior Province. In the high-sulfur category, economically recoverable reserves are 87.5 percent of total deep mine reserves for the same Eastern Interior district, but only 1.2 percent for the same Appalachian district. The sulfur content of the remaining reserves in these two districts is unknown. On the basis of classifying the various districts in the region in terms of low-sulfur, deep-minable reserves, four different producing areas within the ORBES region were identified and were used to perform the scenario coal supply analysis.[2]

When all end-use sectors are considered, coal use accounts for about half of the total conventional fuel consumption in the ORBES region (see figure 4-1).[3] In comparison, coal use accounts for only about one-fifth of the total conventional fuel consumption in the nation. The largest user of coal within the region is the electric utility industry, which accounts for 67 percent of the total coal used in the region. In comparison, the industrial sector is the next largest user of coal and accounts for about 28 percent of the regional coal consumption. However, the 67 percent consumed by the electric utilities constitutes 95 percent of the fuels used for electrical generation in the region (versus 51 percent in the nation). The 27 percent consumed by the industrial sector accounts for only 48 percent of its total consumption.

ELECTRICITY. If all conventional fuels are considered, the electric utility industry consumes about 34 percent of the regional total. Approximately 68 percent of this amount is used to generate electricity; in other words, it takes approximately 2 Btu's of conventional fuels to produce 1 Btu of electricity. Thus, 24 percent of the total regional consumption of conventional fuels actually generates electricity.

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[2] See Walter P. Page, An Economic Analysis of Coal Supply in the Ohio River Basin Energy Study Region (ORBES Phase II).

[3] In this analysis, conventional fuels are defined as coal, petroleum products, natural gas (all uses), plus hydroelectric and nuclear power for the generation of electricity. Total final consumption is defined as consumption in the residential-commercial, industrial, transportation, and miscellaneous sectors, plus the use of energy and fuels for electric power generation (including losses and omissions). See Page, Energy Consumption, for further details on energy and fuel use.

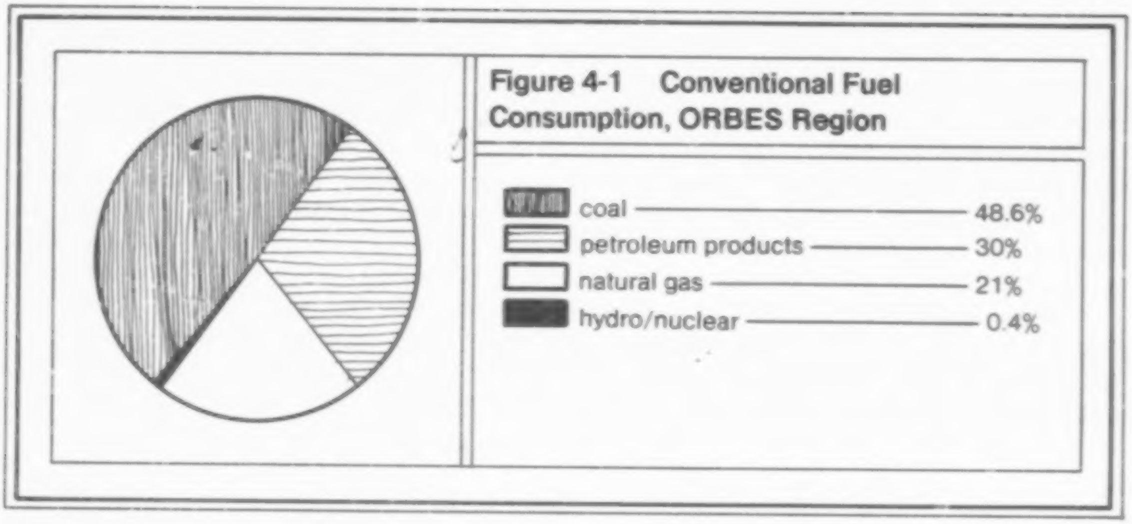

Figure 4-1 Conventional Fuel Consumption, ORBES Region

In 1976 there were 83,125 megawatts electric of installed generating capacity in the ORBES region. Slightly more than half of this regional installed capacity is located in the first two rows of counties along the Ohio River.[4] As already emphasized, coal-fired facilities comprise the majority of these facilities (see figure 4-2).

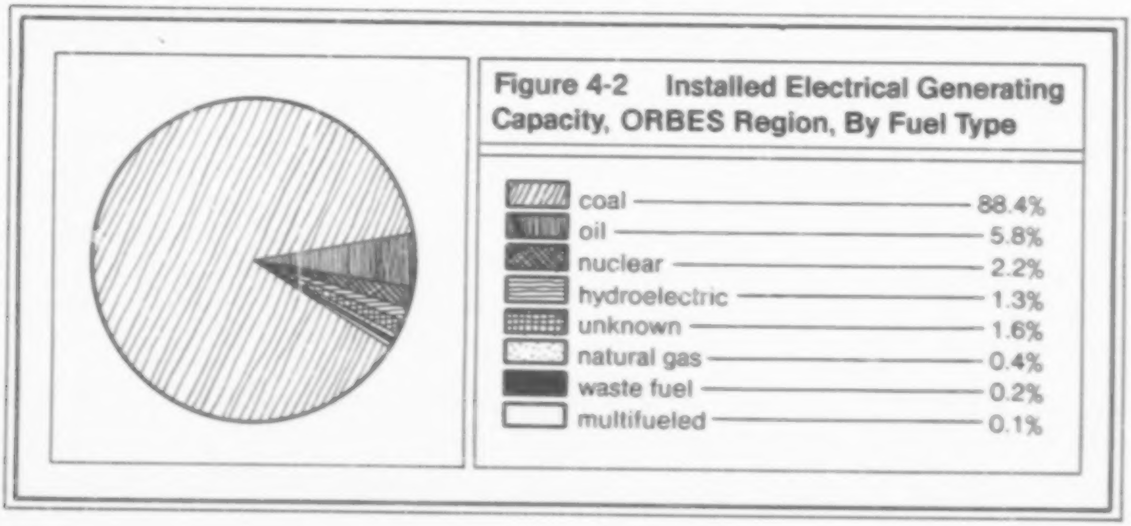

Figure 4-2 Installed Electrical Generating Capacity, ORBES Region, By Fuel Type

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[4] See Steven D. Jansen, *Electrical Generating Unit Inventory, 1976-1986: Illinois, Indiana, Kentucky, Ohio, Pennsylvania, and West Virginia* (ORBES Phase II).

The ORBES region exports a large amount of the electricity it generates. Net regional exports in 1974 totaled about 276 trillion Btu's, or 26 percent of the electricity generated within the region. No ORBES investigation was conducted on the destination of electricity exports. It appears, however, that since the six ORBES states export only 7 percent of their electricity, much of the electricity exported from the study region is used in the northern portions of Illinois, Indiana, and Ohio; central and eastern Pennsylvania; Maryland; and other east coast states.

Nonfossil fuels play an insignificant role in the ORBES region. In 1974, they equaled less than 1 percent of the total conventional fuel use in the region--approximately the same percentage as in the six ORBES states and the nation.

A comparison of the ORBES region and the six ORBES states shows that the region accounts for about half of the six-state total consumption of conventional fuels for all end-use sectors; that the region is highly concentrated in the use of energy for electrical generation; and that the region makes heavy use of coal as a primary fuel.

4.2 Economy

CONTRIBUTIONS TO GROSS REGIONAL PRODUCT. Manufacturing and trade are the two sectors that contribute the most to the ORBES gross regional product--about 31 and 16 percent, respectively.[5] Seven other economic sectors in the ORBES region contributed from 3 to 12 percent each to the gross regional product (see figure 4-3). However, although mining constitutes only 3 percent of the gross regional product and agricultural activities constitute only 4.1 percent, these contributions are higher in the ORBES region than they are in the nation (1.6 and 3.2 percent, respectively).

Of the six ORBES state portions, the Ohio portion contributes the most to the gross regional product--32 percent. The other five state portions contribute from about 6 to 18 percent each. It should be remembered, however, that large metropolitan areas of the ORBES states of Illinois, Indiana, Ohio, and Pennsylvania are excluded from the region. Thus, the gross product of an ORBES state portion may be only a percentage of that state's overall gross product. For example, whereas the ORBES state portion of Illinois contributed

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[5] Gross regional product information is based on 1975 data. For further information on the regional economy, see Walter P. Page and John Gowdy, Gross Regional Product in the Ohio River Basin Energy Study Region, 1960-1975 (ORBES Phase II).

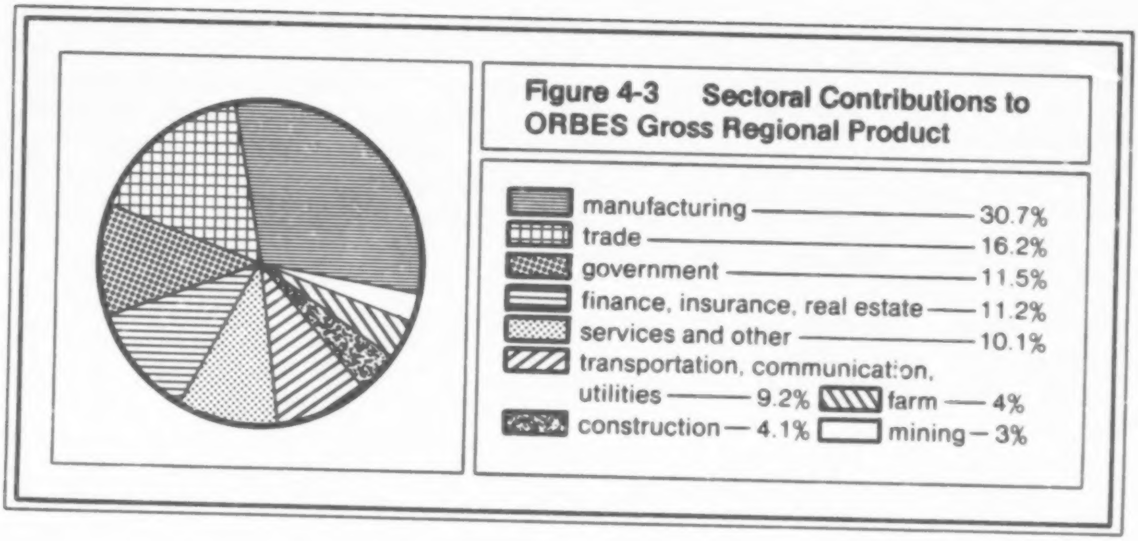
Figure 4-3 Sectoral Contributions to ORBES Gross Regional Product

only 15.4 percent of the 1975 regional gross product, the state of Illinois contributed 29.4 percent of the 1975 six-state gross product.

Since coal mining is closely tied to electrical generation in the ORBES region, it is of interest to see how much this sector contributes to the gross product of each state portion. Of the gross products of the six ORBES state portions in 1975, mining constituted the highest percentages in the West Virginia portion (14.2 percent), the Kentucky portion (5.7 percent), and the Pennsylvania portion (4.1 percent). Mining constituted only 2 percent of the gross product in the Illinois state portion, 0.9 percent in the Ohio portion, and 0.5 percent in the Indiana portion.

GROWTH IN GROSS REGIONAL PRODUCT. Between 1960 and 1975, the growth in gross product in the ORBES region was substantially less than the growth in the gross products of the six ORBES states and the United States in the same period. The overall gross regional product grew at an average annual compounded rate of 2.47 percent while the six-state gross product grew at 2.82 percent and the national gross product at 3.26 percent. During this same period, the most rapidly growing economic sectors in the ORBES region were government (3.43 percent), transportation-communication-utilities (also 3.43 percent), and finance-insurance-real estate (3.41 percent). These growth rates were significantly higher than those of the remaining sectors; the highest of these, the trade sector, grew by 2.80 percent.

In general, however, structural characteristics of the ORBES-region economy--the proportion each sector contributes to the gross regional product--remained stable during this period. The largest percentage increase of a sector's contribution to gross regional product was only 2 percent (in the government sector), as was the largest decrease (in the construction sector).

PER CAPITA GROSS PRODUCT. In 1975, per capita gross product in the ORBES region was \$5205 (approximately \$7027 in 1979 dollars), or 8.6 percent less than per capita gross product in the six ORBES states (\$5695, or approximately \$7688 in 1979 dollars) and 6.7 percent less than per capita gross product in the nation as a whole (\$5578, or approximately \$7530 in 1979 dollars).

4.3 Air

Since the passage of the Clean Air Act in 1963, and especially since the amendments of 1970 and 1977, air quality in the ORBES region has improved (see section 2.1 for a discussion of the Clean Air Act). However, air quality measurements during the study's base period (the mid-1970s) indicate that air quality standards are still not being met at several locations in the ORBES region and that other locations could be close to violation. Here, the base period trends of concern are delineated with representative examples.

COMPLIANCE WITH AIR QUALITY STANDARDS. Air quality measurements indicate that sulfur dioxide pollution problems still exist in the region. In 1977, 11 of the 423 ORBES-region counties violated the national ambient air quality standards (NAAQS) for sulfur dioxide. An additional 13 counties did not have available the full 24-hour prevention of significant deterioration (PSD) increment for sulfur dioxide to accommodate new sources since the ambient concentrations were at or just below the NAAQS. Most of the counties that violated the NAAQS were clustered on the Ohio-Pennsylvania-West Virginia border. However, since over 50 percent of the counties in the ORBES region are without sulfur dioxide monitoring, the number of 1977 violations probably are underestimated.[6]

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[6] For further details, see James J. Stukel and Brand L. Niemann, Documentation in Support of Key ORBES Air Quality Findings, and Teknekron Research, Inc., Air Quality and Meteorology in the Ohio River Basin: Baseline and Future Impacts, vols. I and II, respectively, of James J. Stukel, ed., Ohio River Basin Energy Study: Air Quality and Related Impacts. The 1977 concentration data for sulfur dioxide (and for total suspended particulates) come from National Aerometric Data Bank monitors. The majority of the data used as examples in this delineation of base period trends comes from this latter system, as well as from the EPA's National Emission Data System, the SURE Phase I project (April 1974 to March 1975), and the SURE Phase II project (August 1977 to October 1978). The remaining data used as examples come from such sources as the EPA/DOE Multi-State Atmospheric Power Production Pollution Study, utility monitoring networks, and U.S. EPA Region III.

Nearly four years (1974-77) of sulfur dioxide data from a utility monitoring network located primarily along the Ohio River main stem further indicate that many other areas in the region could be close to violations. According to these data, about half the available annual air resource for sulfur dioxide has been used up around this network in the vicinity of the lower reaches of the Ohio River, and all or nearly all has been used up in the vicinity of the upper reaches. Data from a more regional monitoring network that were collected between August 1977 and October 1978 show that sulfur dioxide annual averages throughout the rest of the region ranged from one-fourth to one-third the annual standard.

The nonattainment of the standards for total suspended particulates (TSP) also has been a problem in the ORBES region. Of the counties that had TSP monitoring in 1977 (again about half), 130 violated the NAAQS for this pollutant; an additional 5 counties had less than the full PSD increment available. Moreover, many of the counties that violated the primary 24-hour NAAQS for TSP were clustered in extreme southwestern Ohio and, again, along the Ohio-Pennsylvania-West Virginia border.

SULFUR DIOXIDE EMISSIONS AND TRANSPORT. The ORBES region is an area of very high sulfur dioxide emission density (mass per unit area). In 1975 the ORBES states were 6 of 10 contiguous states east of the Mississippi River with sulfur dioxide emissions greater than 1 million tons per year. There are 31 states in this area, and in 1975 their sulfur dioxide emissions ranged from 2000 tons (in Vermont) to 3.9 million tons (in Ohio). Moreover, in 1973, 15 air quality control regions (AQCRs) in the ORBES region (or almost 40 percent of the AQCRs completely or partially in the region) had sulfur dioxide emission densities greater than 10,000 kilograms per square kilometer (see figure 4-4).[7]

The primary sources of regional emissions are large, isolated point sources (usually power plants) or complexes of urban and industrial sources. However, coal-fired electrical generating units emit at least 2.4 times more sulfur dioxide than do nonutility sources of this pollutant. Data from the AQCRs over a period of years indicate the predominance of utility sulfur dioxide emissions over nonutility sulfur dioxide emissions within the region. In 1973, in 9 of the 15 AQCRs with high sulfur dioxide emissions, utility sources predominated. Emissions from these sources were 10 or more times

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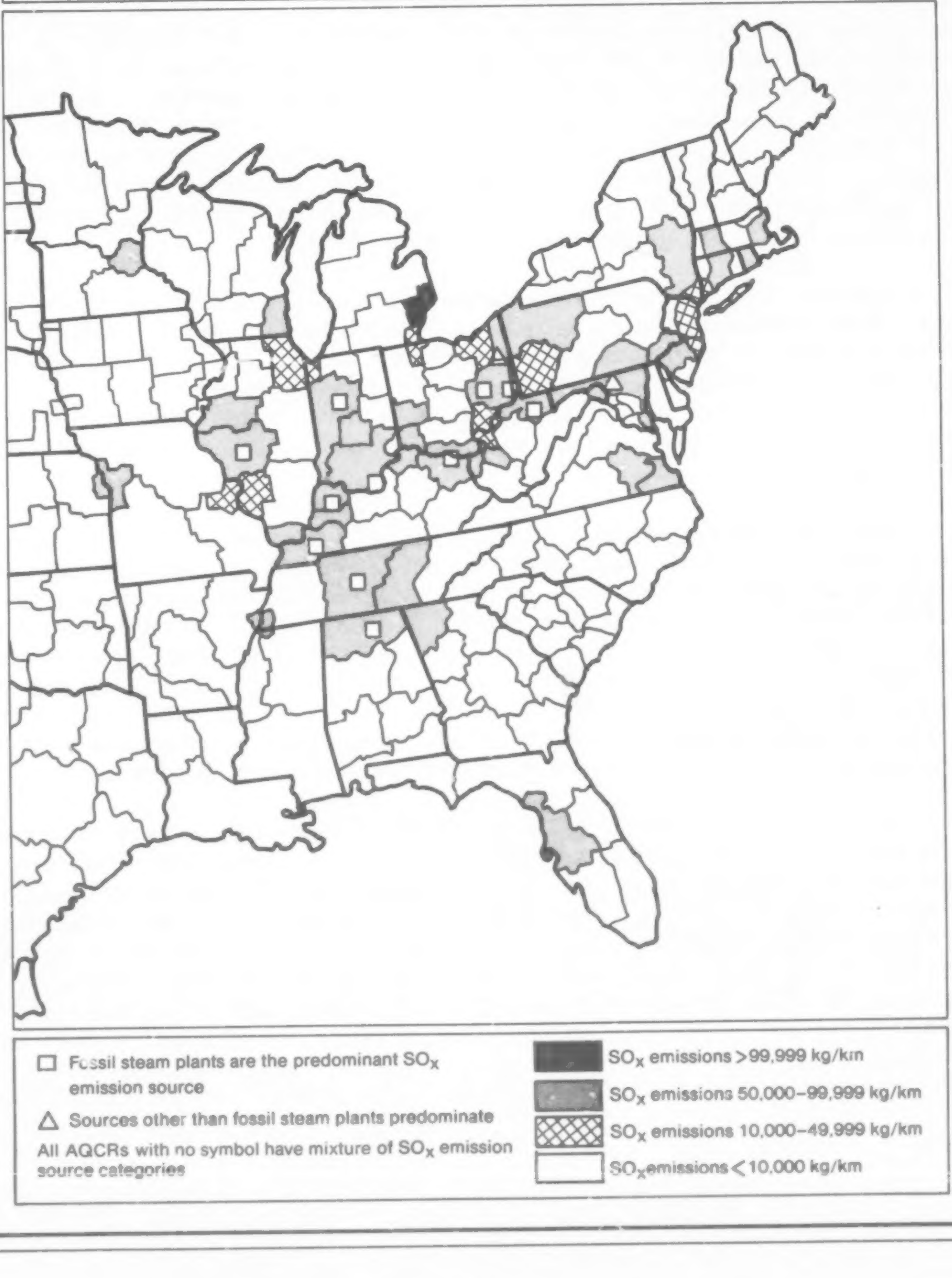
[7] AQCRs are based on jurisdictional boundaries, urban-industrialized concentrations, and such factors as climate, meteorology, and topography. They were created for the purpose of setting ambient air quality standards. AQCR data are coordinated by EPA's National Emission Data System.

Figure 4-4
AQCRs with High Sulfur Dioxide Emission Densities, Eastern United States


☐ Fossil steam plants are the predominant SO_x emission source
△ Sources other than fossil steam plants predominate
All AQCRs with no symbol have mixture of SO_x emission source categories
■ SO_x emissions >99,999 kg/km
▒ SO_x emissions 50,000–99,999 kg/km
▩ SO_x emissions 10,000–49,999 kg/km
☐ SO_x emissions < 10,000 kg/km

those of nonutility sources and accounted for 50 percent or more of the total emissions (see figure 4-4).

Electrical generating facilities in the ORBES region thus provide a majority of total regional sulfur dioxide emissions as well as a significant percentage of national sulfur dioxide emissions. For example, in 1976, ORBES-region coal-fired electrical generating units produced about 78 percent of the regional sulfur dioxide emissions from all sources. In terms of national emission levels in that year, utility sulfur dioxide emissions in the region constituted nearly 52 percent of U.S. electric utility sulfur dioxide emissions and 32 percent of U.S. sulfur dioxide emissions from all sources. In comparison, the ORBES region contained about 36 percent of the national coal-fired electrical generating capacity in 1976.

However, high sulfur dioxide emission densities within any subregion of the ORBES region may not be solely responsible for high sulfur dioxide concentrations in that subregion. Moreover, a location without high sulfur dioxide emissions still can experience high concentrations of this pollutant. The explanation involves the transport of sulfur dioxide emissions--that is, the transport over regional-scale distances on the order of several hundred kilometers.

Regional data indicate that transport of emissions by extremely persistent winds (winds that blow from one direction for extended periods of time) is an important factor in regional sulfur dioxide concentrations. At several locations throughout the region, between 30 and 50 percent of the 25 highest daily sulfur dioxide concentrations each year are associated with transport by extremely persistent winds. Specific data from along the Ohio-Pennsylvania-West Virginia border further indicate that the transport of sulfur dioxide emissions from local and long-range sources contributes to violations of the 24-hour sulfur dioxide standards along that border.

As discussed previously, a large number of ORBES-region counties have TSP concentrations that violate the NAAQS for TSP, or they have available less than the full PSD increment for TSP. However, the TSP concentrations do not represent as much of a constraint to utility growth as do the sulfur dioxide concentrations, primarily because regional utility particulate emissions account for a small percentage of both regional and national emissions. For example, in 1976, ORBES-region coal-fired electrical generating units produced about 22 percent of the regional particulate emissions from all sources, about 50 percent of total U.S. electric utility particulate emissions, and about 7 percent of total national particulate emissions from all sources.[8]

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[8] These calculations do not include "fugitive dust" contributions from unpaved roads and airstrips. If such contributions were considered, regional

SULFATES

Contribution to TSP Nonattainment. However, if utility sulfur dioxide emissions were controlled or if a fine particulate standard were to be implemented, TSP concentrations would decrease dramatically since sulfates would decrease with such controls or such a standard.[9] Although sulfates are directly emitted in small amounts and can occur naturally (though there is controversy as to the amount of this natural occurrence), the transformation of sulfur dioxide to sulfates in the atmosphere contributes the most to sulfate and TSP concentrations. Thus, since utility sulfur dioxide emissions, as already noted, constitute the majority of regional sulfur dioxide emissions, utilities could be implicated in TSP nonattainment more than they are at present if the sulfate contribution to TSP concentrations is examined further.

Data indicate that sulfates are a major contributor to the elevated TSP levels in the ORBES region. During the period August 1977 to October 1978, measurements at least three regional monitoring stations indicated that elevated sulfate concentrations contributed to TSP nonattainment since the 24-hour secondary standard would not have been violated if the sulfate concentration was subtracted from the TSP concentration. During this period, there were 6 cases in the ORBES region (out of the 21 cases observed in the eastern United States) in which the sulfate concentrations caused the 24-hour secondary standard to be exceeded.

Transport. Further data indicate that transport contributes to elevated TSP concentrations. Assuming that sulfate concentrations are a good measure of the contribution of nonlocal sources to local TSP measurements, long-range transport of sulfates over several hundred kilometers contributed between 15 to 20 percent of the total annual TSP concentrations in the upper Ohio River region during the period from 1975 to 1977. Moreover, during a sulfate episode, such as the episode of August 27, 1974, sulfate concentrations can exceed 30 micrograms per cubic meter over a 24-hour period, and the sulfate/TSP ratios can range from 20 to 45 percent.[10] This fact suggests that

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utility particulate emissions would constitute about 16 percent of regional particulate emissions from all sources and about 3 percent of total U.S. particulate emissions from all sources.

[9] Sulfates are a part of the total suspended particulate measurement.

[10] For purposes of ORBES, episodes are defined as days with sulfate concentrations exceeding 20 micrograms per cubic meter at 25 percent or more of the stations reporting; at least 25 percent of the total number of available stations must have reported on that day.

long-range transport contributes 20 to 45 percent of the total measured concentration of TSP under such episodic conditions.

Examination of data at specific sites also indicates sulfate transport trends. In Pennsylvania, for example, long-range transport of sulfur dioxide emissions can contribute significantly (between 25 to 50 percent) to widespread violations of the Pennsylvania sulfate standard and to violations of the federal 24-hour TSP secondary standard in that state. Further analysis of data from the southwestern Pennsylvania border area shows that these high sulfate concentrations are associated more often with long-range transport from the west and southwest (that is, the lower ORBES region) than from the opposite directions.

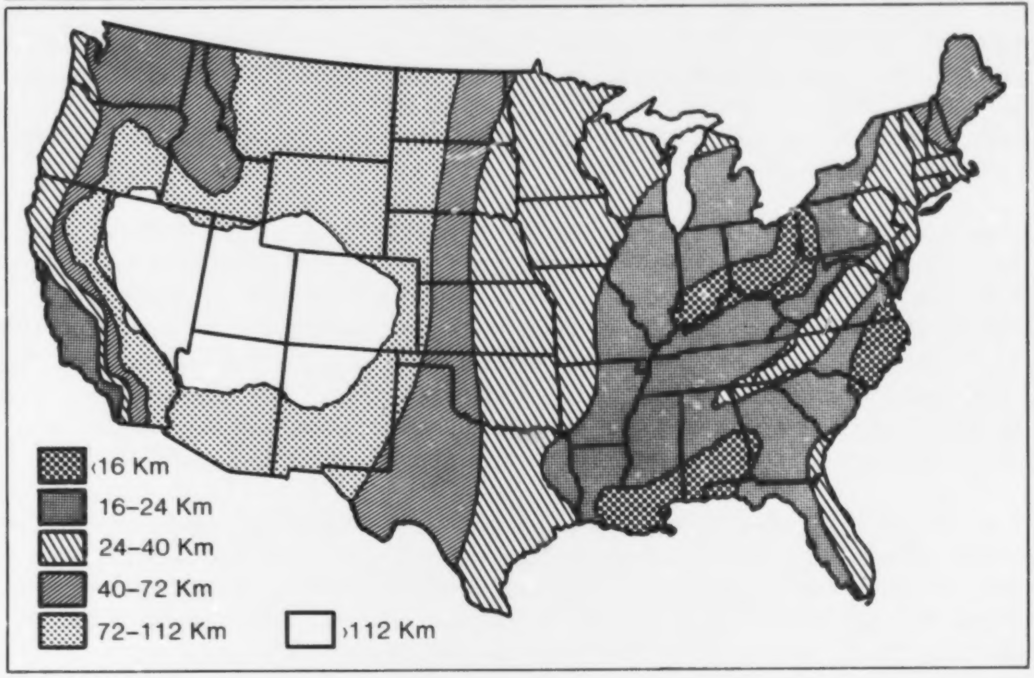
When further impacts of meteorological conditions on sulfate and TSP concentrations are considered, other observations can be made. One observation is that air mass trajectories associated with major sulfate episodes in the northeastern United States and southeastern Canada pass over the ORBES region, strongly implicating it as a major source region for these episodes.

Acidic Precipitation. Sulfate episodes are important to understand since acidic precipitation is due primarily to the presence of sulfate and nitrate ions and since the sulfate ions are estimated to be primarly man made. Precipitation is considered acidic if its pH is less than 5.6, the normal value for natural precipitation. Although data are sketchy for determination of the frequency of acid rain, between November 1978 and May 1979, five stations in or near the ORBES region recorded 41 events in which precipitation pH was less than 5.6. Between September 1978 and May 1979, mean regional pH values were about 4.1; minimum values were about 3.6.

Wet sulfur deposition, or the amount of sulfur that reaches the ground, is another parameter often used to characterize acidic deposition. During the base period, annual wet deposition in the ORBES region tended to be in the middle of the range observed in the eastern United States. In the study region, the range was between 1 and 2 grams of sulfur per square meter per year, with the highest measured values occurring immediately downwind in central Pennsylvania. Moreover, a number of wet deposition episodes (low pH and/or high sulfate ion concentrations) appear to be associated with very light rainfall or with rainfall over a limited area at the end of major ambient sulfate episodes.

Visibility. Understanding regional sulfate episodes also is important since such episodes often are associated with reduced visibility. Based on yearly airport data, the visual range along the portion of Ohio River valley with elevated sulfate concentrations is less than 16 kilometers. The yearly average visibilities outside of the valley but within the six ORBES states range between 16 and 24 kilometers (see figure 4-5).

Figure 4-5
Average Yearly Visibility



Episodes. The significant contribution of both simple and complex meteorological conditions to regional pollutant concentration trends is demonstrated further by four regional sulfate episodes that were evaluated by the Prahm regional transport model. In that evaluation, the subregional sources of these episodes were examined.[11] These four episodes were selected to provide a representative cross-section of flow patterns, seasons, and special situations. They occurred on August 27, 1974; July 10, 1974; June 11, 1976; and June 23, 1975.

The most frequent type of sulfate episode (occurring at least 10 times per year) is exemplified by the August 27, 1974, episode. This type of episode involves a rather straightforward, simple flow pattern of extremely persistent winds blowing from west to east over the ORBES region for several days (see figure 4-6 for a depiction of air mass trajectories during the August 27 episode). Modeling results suggest that, during this episode, sulfur dioxide emissions in the lower ORBES region contributed about 75 percent of the peak sulfate concentrations in the upper region. Nearly 100 percent of the contribution from the lower region came from utility emissions. Thus, under these episodic conditions, modeled sulfur dioxide and sulfate concentrations in an area of the upper region were 94 and 40 micrograms per cubic meter, respectively.[12]

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[11] For a discussion of the regional application of the Prahm model, see Teknekron Research, Inc., Air Quality in the Ohio River Basin. For a discussion of the model itself, see L.P. Prahm and O. Christensen, "Long-Range Transmission of Pollutants Simulated by a Two-Dimensional Pseudospectral Dispersion Model," Journal of Applied Meteorology 16:896-910.

On a state basis, the Prahm model predicts that, during the August 27 episode, utility sulfur dioxide emissions from the ORBES states of Illinois, Indiana, and Kentucky produced peak sulfate concentrations of about 8, 14, and 25 micrograms per cubic meter, respectively, at locations in the upper ORBES region. Isopleth maps of the sulfur dioxide and sulfate concentrations due to utility emissions on August 27 indicate that the area of highest concentrations occurred along the Ohio River main stem and particularly along the Ohio-Pennsylvania-West Virginia border (see figures 4-7 and 4-8).

Although the three other episodes had meteorological patterns different from the August 27 episode and from each other, the Prahm model indicates that the transport of emissions again was an important factor in the concentrations recorded during all three of these episodes. During these three episodes, as in the August 27 episode, sulfur dioxide emissions from all sources in the lower region contributed significantly (as much as 80 percent) to the sulfate concentrations in the upper region. Similarly, utility sulfur dioxide emissions in the lower region alone contributed at least half (and in one episode almost all) of the sulfate concentrations in the upper region. Modeling of the June 23, 1975, episode in particular points up the importance of transport by predicting that utility sulfur dioxide emissions from the upper portion of the ORBES region contributed about 50 percent of the predicted sulfate concentrations in an area northeast of the region. Even under nonepisodic conditions, however, these emissions would have been transported beyond the region and would have contributed to sulfate concentrations beyond the continental United States.

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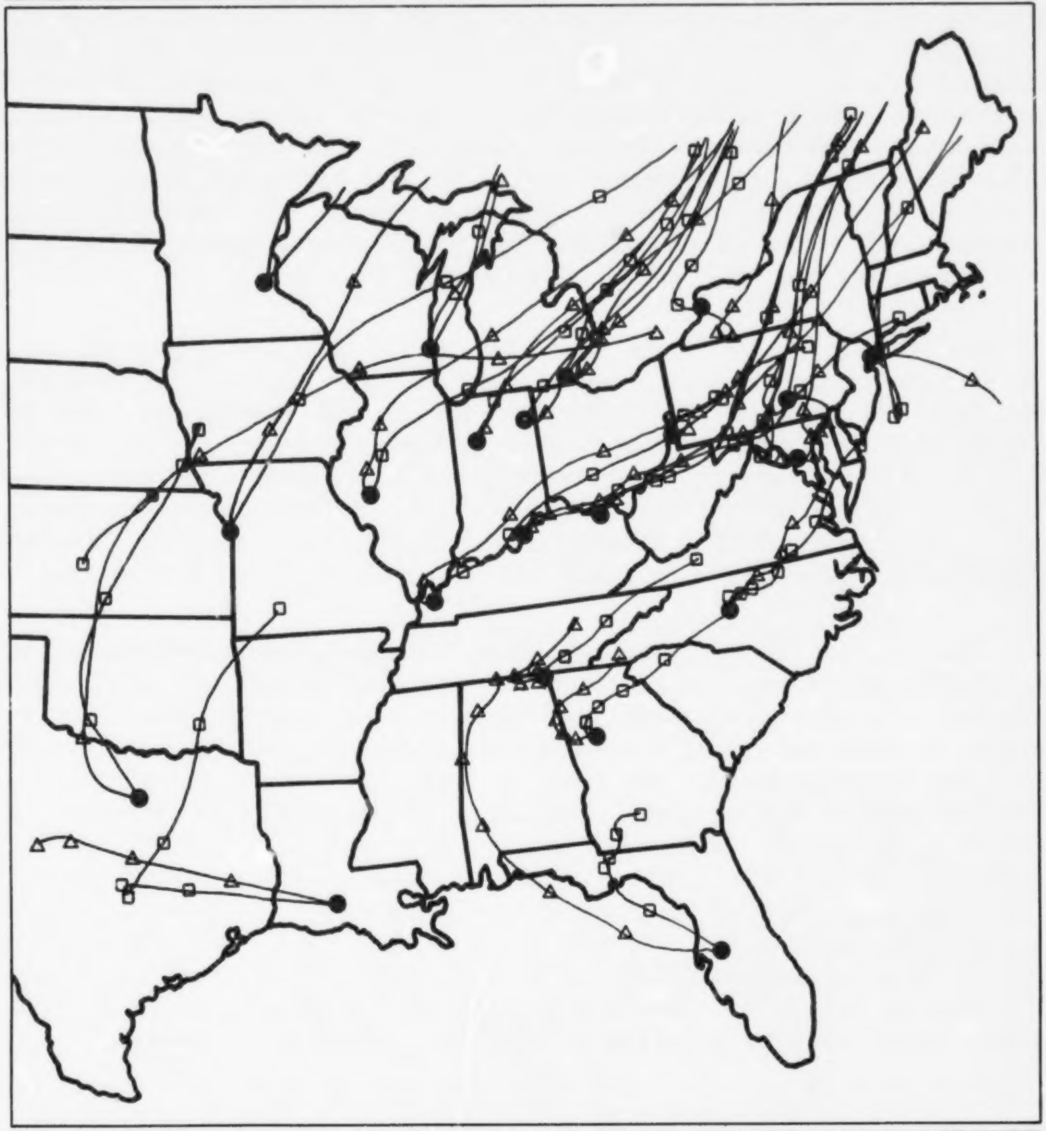
[12] Data for this episode come from the SURE Phase I project, April 1974 to March 1975. An "area" in the SURE project was determined by using a grid pattern of 80-by-80 kilometer squares, and this same averaging method was used in ORBES modeling. Thus, for example, while the area of highest concentration may have had an average sulfate concentration of 40 micrograms per cubic meter, specific locations within or outside the 80-by-80 kilometer area might have experienced higher or lower concentrations.

Figure 4-6
Calculated Air Mass Trajectories at 600 Meters Above the Ground, Eastern United States, August 25, 1974



● Starting point of trajectory on August 25, 1974
□ Twelve-hour interval beginning at noon (Greenwich Median Time)
△ Twelve-hour interval beginning at midnight (Greenwich Median Time)

ANNUAL AVERAGE CONCENTRATIONS. Sulfur dioxide and sulfate concentrations of longer duration also were calculated. While the Prahm regional transport model predicts the impacts of short-term episodes, the TRI/Fay model predicts long-term aspects, such as annual average concentrations and their sources.[13] One of the model's predictions is that utility sulfur dioxide emissions in the ORBES region contribute about 75 percent of the annual regional sulfur dioxide and sulfate concentrations. Another prediction is that the long-range transport of utility sulfur dioxide emissions contributes about 30 percent of the observed annual sulfur dioxide concentrations in the industrialized areas of the upper ORBES region. Figures 4-9 and 4-10 show that the annual average sulfur dioxide and sulfate concentrations in 1976 due to utilities were higher in the upper ORBES region than in the lower region. In the area of highest concentration, 1976 modeled sulfur dioxide and sulfate concentrations were 26 and 9 micrograms per cubic meter, respectively.

The TRI/Fay model also was used to assess an individual state's contribution to the annual concentrations in other states. For example, the model predicts that of the 10 states east of the Mississippi with sulfur dioxide emissions greater than 1 million tons per year, the sulfur dioxide emissions from Ohio contribute between 3 and 4 micrograms per cubic meter to the annual sulfate concentrations in the states of Pennsylvania, Maryland, and West Virginia. Within Ohio itself, sulfur dioxide emissions contribute over 4 micrograms per cubic meter to annual sulfate concentrations in that state.

Finally, the TRI/Fay model was used to assess the relationship between the ORBES region and southeastern Canada in regard to sulfur dioxide emissions, pollutant concentrations, and transport impacts. The total sulfur dioxide emission rate from eastern Canadian sources (east of 105 degrees west longitude) is about 4.6 million tons per year. In comparison, Ohio--the state with the highest sulfur dioxide emissions in the United States--has sulfur dioxide emissions of about 3.45 million tons per year. Despite the high emissions in eastern Canada, sulfur dioxide emissions from this area contribute only about 2 micrograms per cubic meter to the annual sulfur dioxide and sulfate concentrations in the northeastern United States. However, sulfur dioxide emissions from electrical generating units in the six ORBES states contribute about 50 percent of the annual sulfur dioxide and sulfate concentrations estimated to occur in southeastern Canada.

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[13] For a discussion of the TRI/Fay model, see James A. Fay and Jacob T. Rosenzweig, "An Analytical Diffusion Model for Long Distance Transport of Air Pollutants," Atmospheric Environment 14:355-65. For a discussion of the regional adaptation of the Fay/Rosenzweig model, see volume II of the air quality report: Teknekron Research, Inc. (TRI), Air Quality and Meteorology in the Ohio River Basin: Baseline and Future Impacts.

Figure 4-7
Sulfur Dioxide Concentrations, August 27, 1974

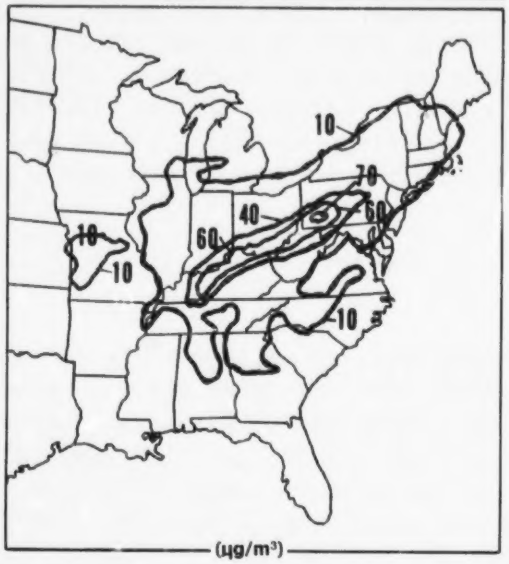

10
70
40
60
60
10
10
10
(µg/m³)

Figure 4-8
Sulfate Concentrations, August 27, 1974

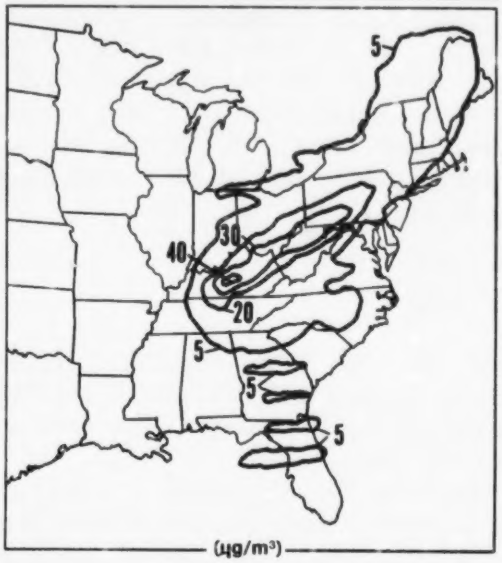

5
30
40
20
5
5
5
(µg/m³)

Figure 4-9 Annual Average Sulfur Dioxide Concentrations

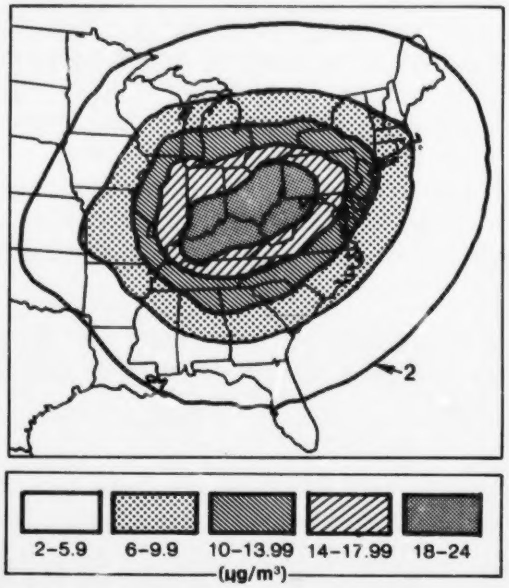
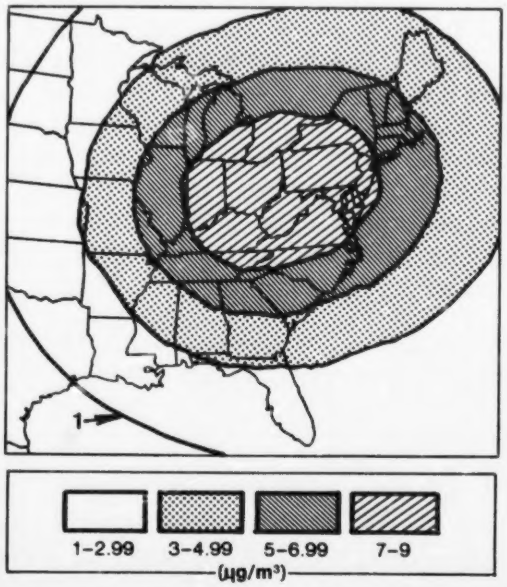

2
2–5.9
6–9.9
10–13.99
14–17.99
18–24
(µg/m³)

Figure 4-10 Annual Average Sulfate Concentrations


1
1–2.99
3–4.99
5–6.99
7–9
(µg/m³)

Thus, both actual measurements during the base period and mathematical modeling of base period concentrations support the importance of transport in sulfur dioxide and sulfate concentrations as well as the contribution of regional emissions to both local and distant concentrations.

NITROGEN OXIDE EMISSIONS. Emissions of nitrogen oxides also were examined briefly. In the mid-1970s, power plants in the ORBES region contributed about 47 percent of regional nitrogen oxide emissions from all sources. In terms of national emissions, nitrogen oxide emissions from regional facilities constituted about 21 percent of total U.S. electric utility emissions of nitrogen oxides and about 6 percent of U.S. emissions of nitrogen oxides from all sources.

4.4 Land

LAND USE. The ORBES region covers approximately 122 million acres (or about 190,000 square miles) in six states. Except for the ORBES state portion of Pennsylvania, at least 75 percent of each state is included in the study region (see figure 1-1).[14] The predominant land use is agriculture (accounting for 54 percent of regional acreage), which ranges from vast corn and soybean tracts in Illinois to smaller tobacco farms in Kentucky. Regional forest area, the next highest land use category in the region, accounts for 31 percent of the regional acreage. The remainder of the region is comprised of urban and built-up areas (6 percent), public lands (4 percent), and miscellaneous uses, including surface and underground mining areas (5 percent).

The two major land uses tend to be subregional, with agricultural land use dominating in the Eastern Interior Coal Province states, and forest areas dominating in the Appalachian Coal Province states (see figure 4-11). Given the land use distribution within the region, it is clear that the greatest potential for conflict between agricultural and energy-related land use--especially the surface mining of coal--occurs in the Eastern Interior Province, particularly in Illinois. Conversely, the greatest potential for conflict between forest and energy-related land use occurs in the Appalachian Province, especially in West Virginia.

COAL MINING. At present, approximately two acres of land must be surface mined in the Appalachian Province to yield the same amount of coal as one acre

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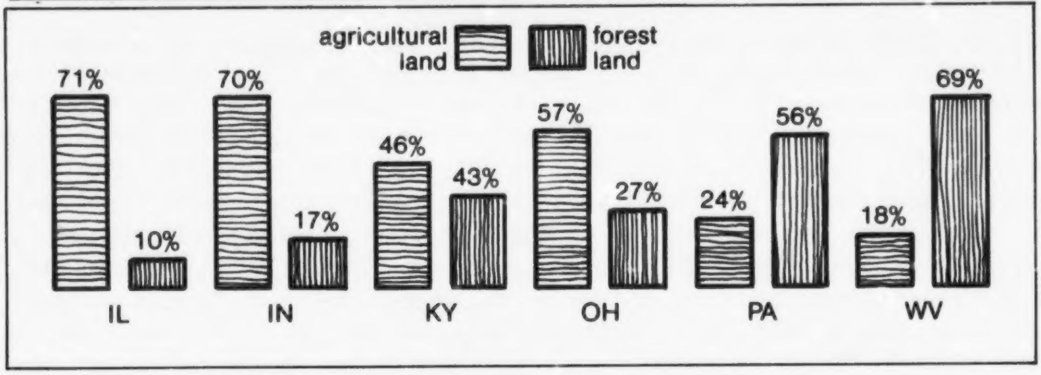
[14] For additional details on land use in the study region, see two ORBES Phase II reports: J.C. Randolph and W. W. Jones, Ohio River Basin Energy Study: Land Use and Terrestrial Ecology, and Daniel E. Willard et al., A Land Use Analysis of Existing and Potential Coal Surface Mining Areas in the Ohio River Basin Energy Study Region.

Figure 4-11
Percentage Agricultural and Forest Land, by ORBES State Portion



in the Eastern Interior Province. Given this fact and the fact that a longer time is required for the regrowth of forests in contrast to the regrowth of pastures, more time and money is necessary to restore a surface-mined site in the former province than in the latter; the requirements of the Permanent Regulatory Program of the Surface Mining Control and Reclamation Act of 1977 would increase these expenditures. Ecological disruption also is severer in the former province than in the latter, especially if the land is not returned to its original forest coverage.

In general, the reclamation of surface-mined land for permanent land use tends to be a slow process. A minimum of two years from the cessation of surface mining is required just to reclaim the land with quick-growing cover species. In 1976, 151,000 acres in the ORBES region were undergoing the two-year reclamation process. Additional data show that another 400,000 surface-mined acres were at least 16 years old in 1976 or only partially reclaimed, or both.

Underground mining also can degrade surface land quality through the improper disposal of mined residuals and through subsidence of the land surface. Mined residuals can cause local problems, but these problems can be controlled by the same reclamation techniques used for surface mining. Land surface subsidence can affect large areas but can be minimized by using longwall mining techniques and by leaving 50 percent or more of the coal seam unmined.

ENERGY-RELATED LAND USE. If all energy-related land uses through 1976 are considered, total energy-related land use in the ORBES region (including past and present surface mining for coal) had affected about 1.5 percent of the regional acreage (1.86 million acres). Land use for past and present surface mining of coal represents 86.9 percent of this figure (1.6 million acres); electrical generating facilities, 7.6 percent (140,700 acres);[15] and transmission line rights-of-way, 5.5 percent (103,000 acres).

PHYSICAL CROP LOSSES. Evidence exists in the literature to indicate that agricultural and natural vegetation can undergo physiological changes due to present air quality.[16] It has been recognized widely that very high short-term ozone exposures can cause visible vegetation damage (a criterion used in deciding the current federal ambient air quality standards for ozone). However, more recent literature indicates strongly that chronic exposures to low ozone (and sulfur dioxide) concentrations can have effects on yield comparable to the results from acute exposures. For example, chronic exposure to 0.05 parts per million of ozone has been shown to cause significant vegetation damage that is not visibly apparent at first.[17] Moreover, power plant nitrogen oxide emissions and nonmethane hydrocarbons have been shown to increase ozone concentrations significantly under certain weather conditions. Thus, one of the matters examined in this study with respect to land quality is the contribution of nitrogen oxide emissions in the ORBES region to ozone concentrations and, thus, to regional crop losses.

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[15] The average land ownership at electrical generating facilities using cooling towers is 1100 acres per 650 megawatts electric. Of this amount, 400 acres are affected directly; 700 acres are affected indirectly. In general, the 400 directly affected acres are comprised of building sites (approximately 6 percent), fuel and waste storage areas (approximately 44 percent), and roads, parking lots, and miscellaneous uses (50 percent). In cases where surface water resources are insufficient to meet cooling needs and cooling reservoirs are required, an additional 975 acres per 650 megawatts would be needed on the average. These figures are based on a study of six representative generating facilities in the ORBES region. See Randolph and Jones, Ohio River Basin Energy Study: Land Use and Terrestrial Ecology.

[16] For a review of the pollutant response literature and for the calculation of crop and forest losses in the ORBES region, see Orie Loucks et al., Crop and Forest Losses Due to Current and Projected Emissions from Coal-Fired Power Plants in the Ohio River Basin (ORBES Phase II). Estimates of crop losses due to ozone formed by nitrogen oxides are annual estimates. Loss estimates related to sulfur dioxide assume the peak load operation of power plants. Forest losses are estimated based on total annual power plant emissions.

[17] Air impact modeling examined the regional impacts of sulfur dioxide, particulate, and nitrogen oxide emissions but did not examine the effects of ozone. See Loucks, Crop and Forest Losses, for information on ozone.

From the evidence gathered, it appears that ozone concentrations in the rural areas of the ORBES region are high enough and of sufficient duration to cause negative responses in vegetation and crops. A further examination reveals that natural events in the region do not account for these high ozone concentrations; hydrocarbons from regional forests and agricultural crops are rarely as important for the production of ozone as are nitrogen oxides, which are produced primarily from transportation sources (about 35 percent) and from power plants (about 50 percent).

Given the regional nitrogen oxide levels in 1976, crop loss estimates were derived based on numerous controlled field studies throughout the eastern United States. These estimates are expressed as lower bound (minimum) values, representing the most conservative assumptions possible, to upper bound (maximum) values, reflecting likely aggregate plant response during sensitive growing conditions and life-cycle stages. These estimates also utilize cumulative ozone exposures from ozone monitoring at various locations in the ORBES region.

Soybean, corn, and wheat yields were examined. Three-year yields (1975 to 1977) for each crop were averaged to obtain a mean normal yield for each affected county in the ORBES region. The results show the total annual production in the ORBES region for corn to be 2.11 billion bushels; for soybeans, 550 million bushels; and for wheat, 180 million bushels. Because this normal yield already includes the effects of air pollutants present in the base period, a probable "clean air" yield was calculated. Thus, the projected losses for the three crops can be considered equivalent to the potential crop production gains achievable from complete pollution abatement. As the projected gains from complete abatement, these numbers provide a comparative idea of what current pollution levels cost in terms of yield as well as what yields complete abatement would provide.

It is projected that 1976 regional crop gains due to the complete abatement of oxidants formed by regional nitrogen oxides could have ranged from a minimum of 118 million bushels to a maximum of 480 million bushels, with 258 million bushels representing the probable gain. Soybeans are estimated to account for 30 percent of the probable gain; corn, 66 percent of the probable gain; and wheat, 4 percent of the probable gain. It also should be kept in mind that what was lost in 1976, therefore, is not merely a local problem--that is, only in the vicinity of power plants--but, because of pollutant transport, the losses may occur in areas of the region removed from major point sources. In addition, about 95 percent of these losses are projected to have occurred in the ORBES state portions of Illinois, Indiana, and Ohio.

Studies in the literature also indicate that sulfur dioxide concentrations of 130 micrograms per cubic meter (one-tenth of the three-hour secondary standard) in the presence of moderate ozone levels (0.06 to 0.1 parts per million) cause additional local vegetation damage and, thus, crop losses. (Sulfite has been identified as the chemical form largely responsible for causing sulfur-dioxide-related injury within the plant system.) Approximately 9.3 percent of the acreage in the ORBES region experienced such sulfur dioxide concentrations in 1976 due to power plant emissions. The percentage of area affected in the six ORBES state portions ranged from 6.9 percent of the Illinois portion to 18.1 percent of the Ohio portion.

Regional crop losses in 1976 due to these concentrations were estimated, and these losses retain the same features as the projected ozone-related losses: upper and lower bounds as well as the concept of the yield that could be gained due to complete abatement. The 1976 crop gains that could have been achieved from complete abatement of sulfur dioxide concentrations are estimated to range from 867,000 bushels to 6.1 million bushels, with 3.2 million bushels representing the probable gain. About 45 percent of the probable gain would come from soybeans; 43 percent, from corn; and 12 percent, from wheat. Again, about 95 percent of the probable gain would occur in the ORBES state portions of Illinois, Indiana, and Ohio.

The amount of corn, soybean, and wheat that was lost in 1976 because of the existing sulfur dioxide concentrations is estimated to be less than 1 percent of the total regional production in 1976. However, on a more local scale, such as the county, the losses may be significant, and the losses to individual farmers near sources of sulfur dioxide may be substantial. Furthermore, whether plants develop tolerances to sulfur dioxide or to ozone is placed in doubt by the fact that pollutant-induced physiological disruptions, including disruption of translocation, may speed up the aging process in plants.

FOREST LOSSES. Forest species also experience problems at the current air pollution levels; species like the catalpa, the American elm, the eastern white pine, the maple, and the Lombardy poplar are susceptible to visible injury from current sulfur dioxide levels. In general, oxidants--and, locally, sulfur dioxide--result in reduced vigor and growth in forest species. Moreover, since pollutant-affected forest species may become too weak to resist insect damage, additional losses due to insect damage also might be attributable to air pollution. However, estimates of reduced growth due to such insect damage cannot be made at this time. Thus, total forest losses, due primarily to ozone, are estimated to have ranged between 0.7 and 3.4 percent of total annual regional growth in 1976.

TERRESTRIAL ECOSYSTEMS. The four terrestrial ecosystem components examined for purposes of ORBES include those for which a somewhat homogenous data base was available: the percentage of forest lands, the percentage of Class I and II soils, the number of natural areas, and the number of endangered species.[18]

Class I and II soils reflect the highest degree of productivity; 39 percent of the ORBES region consists of Class I and II soils, ranging from 58 percent of the ORBES portion of Indiana to 6 percent of the ORBES portion of West Virginia.

Natural areas, which contain unique biological, geological, or scenic features, can serve, in their distribution and abundance, as overall indicators of environmental quality. The number of natural areas within the ORBES state portions varies considerably, however, because of different emphases placed on natural area programs by the six states. For example, Illinois has the greatest number of recognized natural areas (426) while Kentucky, with the lowest number, has only 67.

Finally, the number of endangered species reflects the high susceptibility of certain of the region's ecosystems to even minor changes. Riparian habitats (those bordering water) generally support the greatest number of rare or endangered species in the ORBES region. Each state has its own list of such species. Only one of these species--the Indiana bat--is on the federally recognized list of endangered species.

Values for each of these variables in 1976 were indexed by units ranging from 1 (low) to 10 (high). These units were weighed equally and summed to produce a county-level index. State totals then were summed. However, no absolute threshold values for assessment unit totals indicate "good" or "poor" ecological quality, but these units do provide a means of making relative comparisons among the ORBES scenarios. Terrestrial ecosystem units in each ORBES state portion in the base year (1976) were assigned as follows: Illinois, 290 units; Indiana, 209; Kentucky, 165; Ohio, 297; Pennsylvania, 192; and West Virginia, 154.

4.5 Water

WATER SYSTEMS. The ORBES region encompasses most of the Ohio River Basin, the portion of the Mississippi River Basin that borders the states of Illinois and Kentucky, and the southern periphery of some Great Lakes drainages.

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[18] For a complete discussion of the terrestrial ecosystem analysis, see Randolph and Jones, Ohio River Basin Energy Study: Land Use and Terrestrial Ecology.

Consequently, the water systems in the ORBES region and the aquatic life they currently support are quite varied.[19] These regional systems include whitewater canoe and mountain trout streams, deep, clear lakes popular as recreational spots, major rivers both navigable and free flowing, and numerous wetlands and sloughs found both in mountain valleys in the east and along the major river basins in the west. In addition, there are a number of accidental lakes created by abundant rainfall in combination with poor farming, foresting, and mining practices. Moreover, in late summer, navigable pools on the Ohio River main stem become long, narrow lakes.

The Ohio River main stem is the major navigable river of the ORBES region. This system connects the industrial eastern portion of the region to its western agricultural base and, since completion of the high-lift dam system, serves as an almost open river from Pittsburgh, Pennsylvania, to Cairo, Illinois. The region's other navigable rivers are the Mississippi, the Illinois, the Tennessee, the Cumberland, the Green, the Kentucky, the Kanawha, the Monongahela, the Allegheny, and the Kaskaskia. With the exception of the Mississippi, these rivers are somewhat smaller than the Ohio, have lower lift lock chambers, and carry considerably less traffic. At present, consideration is being given to the closing of some of the smaller systems, for example, the Kentucky River.

AQUATIC ECOLOGY. The richness of the region's aquatic ecology can be seen in the diversity of the fish species found in the 70 streams and rivers selected for specific analysis. Of the 258 fish species in the ORBES region, 25 are regionally ubiquitous (occurring in 60 of the 70 selected ORBES-region waterways), 102 are dispersed (occurring in 11 to 59 of the 70 selected waterways), 97 are limited (occurring in 2 to 12), and 34 are isolated (occuring in only 1 of the selected waterways). However, a species regionally isolated in a specific stream should not be considered endangered--except in the case of the Scioto madtom--since many of these isolated species are hybrids of common types and others are peripheral and occur in the ORBES region simply because it borders their range.

All of the regional water systems--the navigable waterways, the tributaries, and the lake systems, for example--exhibit rich aquatic ecologies. The bank systems of the region's navigable waterways, in particular, are the ecological mainstay of these diverse habitats. The lower Ohio (from Cincinnati, Ohio, to Cairo, Illinois), the Tennessee, the

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[19] For a description of the region's water systems and a discussion of its aquatic ecology, see Clara Leuthart and Hugh T. Spencer, Fish Resources and Aquatic Habitat Impact Assessment Methodology for the Ohio River Basin Energy Study (ORBES Phase II).

Cumberland, and the Mississippi rivers each contain some 90 fish species, including many important game species.

The ORBES-region tributaries contain more site-specific ecosystems than the navigable waterways. Some entirely unique systems, which are protected to a degree, are evident in the tributaries. The most outstanding and ecologically rich stream system of the 70 regional streams and rivers selected for study is the Bayou de Chien-Obion Creek system, which is located in Kentucky. One hundred and eight species live in this small system of sluggish streams and wetlands, including eight isolated species, the most of any regional stream system studied.

The regional lake systems also have diverse ecologies. For example, Lake Barkley, part of the Cumberland River system, contains 128 fish species--the most of any lake system in the region. Kentucky Lake, part of the Tennessee River system, contains 101 fish species--the second highest number in the region. Lake Barkley and Kentucky Lake also are the largest lakes in the region.

WATER RESOURCES. The water resources that support these systems and their habitats come from both within and outside of the region. Within the region, stream flow (measured in cubic feet per second) is aided by precipitation runoff, groundwater, and reservoirs. Although the average annual rainfall in the ORBES region results in a potential water supply to the region of about 584,000 cubic feet per second, the runoff that actually reaches the region's streams is, under average conditions, about 216,000 cubic feet per second. River inflows from outside the region also make major contributions to regional water supply. The inflow under average conditions is about 257,000 cubic feet per second. Thus, the total water supply in the ORBES region under average conditions is about 474,000 cubic feet per second.[20]

Besides supporting the waterways and the aquatic life of the region, this water supply also is heavily used by industries, municipalities, and electric utility companies. As a result of this use, a certain amount of the region's water supply is lost through consumption (evaporation). In 1970, for example, it is estimated that municipalities in the ORBES region consumed 500 million gallons per day (or 774 cubic feet per second) and that self-supplied industries, excluding the electric utility industry, consumed 720 million gallons per day (or 1120 cubic feet per second). It is estimated that in 1975 water consumption by the electric utility industry totaled 564 cubic feet per second.[21]

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[20] For calculation of the water supply available to the ORBES region, see E. Downey Brill, Jr., et al., Potential Water Quantity and Water Quality Impacts of Power Plant Development Scenarios on Major Rivers in the Ohio Basin (ORBES Phase II).

WATER QUALITY. Within the region, water quality standards vary from state to state and even from river to river. For purposes of ORBES, however, one reference concentration was selected for each pollutant to facilitate the scenario examinations of the potential regionwide water quality impacts of power plant discharges. Each reference was selected by considering the water quality criteria of the six ORBES states, the Ohio River Valley Water Sanitation Commission (ORSANCO),[22] and the U.S. Environmental Protection Agency. Table 4-1 lists the ORBES reference concentrations that were selected for 20 pollutants; the table also lists the standards or criteria recommended by each state, ORSANCO, and EPA.

Seven-Day-10-Year Low Flow. The concept of 7-day-10-year low flow also was used in the study. This concept is a design parameter commonly used in river basin management and water quality assessments, primarily as a worst case decision tool or parameter. In the simplest of terms, it is the lowest flow that would be expected to occur on the average for seven days at least once every 10 years. During 7-day-10-year low flow, regional water supply drops, on the average, to about 88,000 cubic feet per second, compared to about 474,000 cubic feet per second under average conditions. Specific flow numbers also are given for each stream reach and can be influenced by impoundment management above that reach as well as by land use in the immediate area. For example, 7-day-10-year low flow in 1930 at the McAlpine lock and dam on the Ohio River (mile point 606.8) was projected to have been 6000 cubic feet per second. This projection was based on the historical record available at the time and on knowledge of how impoundment releases in the region above mile point 606.8 were managed. The same projection for the same mile point today stands at about 14,700 cubic feet per second, more than double the 1930 value. In the interim, many impoundments have been added to regional waterways, and their influence on the projection is obvious. However, the region's current 7-day-10-year low flow projections also are affected significantly by two other factors: (1) these projections are based on an average and (2) severe drought conditions, which could affect that average, have not occurred in the region since 1930.

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[21] These estimates were calculated assuming that municipal consumption would be 20 percent of projected withdrawals and that industrial consumption would be 10 percent of the withdrawals that were projected using manufacturing earnings. These percentages are considered to represent the most probable consumption factors. However, a range of estimates exists. A low estimate projects a combined municipal and industrial consumption of 810 million gallons per day, and a high estimate projects a combined consumption of 1400 million gallons per day. Projections about consumption by the power generation industry were based on varying assumptions under different cooling alternatives. For a discussion of these more complex assumptions as well as for projections about future water consumption, see Brill, Potential Water Quantity and Water Quality Impacts.

[22] The ORSANCO criteria apply only to the main stem of the Ohio River.

Travel times on the region's major river systems at 7-day-10-year low flow greatly exceed seven days, making the analysis essentially reach specific. For example, travel time for the Ohio River main stem at 7-day-10-year low flow is 192 days. Thus, the projected impacts under 7-day-10-year low flow are not assumed to occur simultaneously. The impact for each river is considered basin specific and, with the obvious exception of a major receiving stream like the Ohio, may or may not occur in association with any other river's impact.

Protection Levels. Based on the number of ubiquitous, dispersed, limited, or isolated fish species, on normal flow conditions, and on certain rules and definitions, each of the 24 ORBES-region streams selected for the most detailed analysis was assigned a protection level (A, B, C, or D) to indicate its current status and to provide comparisons among scenarios.[23] A stream received an aquatic habitat ranking of "A" if it could not experience stress without undergoing a structural change in the direction of degradation. Eighteen of the 24 streams have this ranking and should be considered high-quality streams. The other 8 have a ranking of "B," which designates that they are in a transitional state between high and low ranking, but closer to a high ranking. A ranking of "C" indicates the same transitional state but indicates that the stream is closer to a low ranking. A ranking of "D" designates low-quality streams that already are degraded and that have a fauna tolerant to pollutants.

Of these 24 waterways, 6 are in Kentucky, 5 in Illinois, 4 in Ohio, 3 in Pennsylvania, 2 in West Virginia, and 2 in Indiana. One of the 2 remaining rivers, the Wabash, borders Indiana and Illinois; the other, the Ohio, borders all six ORBES state portions (see figure 4-12).

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[23] The 24 largest streams in the region were selected for more detailed analysis out of 70 streams studied because they have the most potential to be selected for power plant siting. For a discussion of the protection levels and of the other streams studied, see Leuthart and Spencer, Fish Resources and Aquatic Habitat Impact Assessment Methodology.

Table 4-1
ORBES Reference Concentrations and Water Quality Criteria and Standards in Effect in the ORBES Region

Constituent	ORBES Reference Concentrations (mg/1)	U.S. EPA Criteria (mg/1)		ORSANCO Criteria (Ohio River Main Stem) (mg/1)	State Standards (mg/1)			
					Illinois[1]			
		Domestic	Aquatic		Domestic	General	Indiana	Kentucky
TDS	500	250[3]	N	500	500	1000	750	500
TSS	50	[5]	N	N	N	N	N	N
Sulfate	250	[3]	N	250	250	500	250	N
Ammonia	1.10	1.1[6]	N	N	N	1.5	N	N
Arsenic	.05	.05[8]	N	.05	.1	1.0	N	.05
Barium	1.0	1.0	N	1.0	1.0	5.0	N	1.0
Cadmium	.01	.01	[9]	.01	.01	.05	N	.01
Chloride	250	[3]	N	250	250	500	250	N
Chromium	.01	.05	.01	.05[10]	.05	1.05	N	.05[10]
Phosphorus	.05	N	N	N	N	.05	N	N
Selenium	.01	.01	.01L	.01	.01	1.0	.01L	.01
Silver	.005	.05	.01L	.05	N	.005	.01L	.05
Copper	.06	1.0	.1L	.1L	N	.02	.1L	.1L
Iron	.30	.30	1.0	N	N	1.0	N	N
Lead	.05	.05	.01L	.05	.05	.1	.01L	.05
Manganese	.05	.05	.1	N	.05	1.0	N	N
Mercury (μg/l[3])	.05	2.0	.05	.2	N	.5	N	N
Nickel	1.00	N	.01L	N	N	1.0	.01L	.1L
Zinc	.205	5.0	.01L	.01L	N	1.0	.01L	.1L
Boron	1.00	[12]	N	N	N	1.0	N	N

The ranking of each of these 24 streams during the base period and under normal flow conditions is indicated in table 4-2, along with the number of reaches into which each stream was divided for purposes of the analysis, the river's expected low flow, and the pollutants that are projected to have been in violation of the study's reference concentrations at some point in 1976 if 7-day-10-year low flow had occurred. As the table indicates, approximately 19 of the region's 24 largest streams would have violated at least three of the ORBES reference concentrations at some time in 1976. The conservative agents in most frequent violation at 7-day-10-year low flow are phosphorus, iron, manganese, copper, and chromium.

Table 4-1 (continued)
ORBES Reference Concentrations and Water Quality Criteria and Standards in Effect in the ORBES Region

State Standards (mg/1)

Constituent	Ohio[1] Domestic	Ohio[1] Aquatic	Pennsyl-vania	West Virginia[2]	Constituent	Ohio[1] Domestic	Ohio[1] Aquatic	Pennsyl vania	West Virginia[2]
TDS	500^4	1500^4	500	N	**Selenium**	.01	.01L	N	.01
	(150)	(150)			**Silver**	.05	.01L	N	.05
TSS	N	N	N	N	**Copper**	1.0	.06^{11}	.1L	.1L
Sulfate	250	N	250	N	**Iron**	.3	1.0	1.5	N
Ammonia	N	1.4^7	.5	N	**Lead**	.05	.03	.05	.05
Arsenic	.05	N	.05	.01	**Manganese**	.05	N	1.0	N
Barium	1.0	N	N	.50	**Mercury (μg/1)**	2.0	.05	N	N
Cadmium	.01	.012	N	.01	**Nickel**	N	.01L	.01L	.1L
Chloride	250	N	150	100	**Zinc**	5.0	.205^{11}	.01L	.1L
Chromium	.05	.1	.05	.05^{10}	**Boron**	N	N	N	N
Phosphorus	N	N	N	N					

N: No standard

L: 96-hour LC_{50}

[1] Toxic substance < 0.1 (96 LC_{50}) or 0.1 (96-hour median tolerance limit)

[2] Assuming Kanawha River criteria and all toxic substances < 0.1 (96-hour median tolerance limit)

[3] For chlorides and sulfates

[4] May exceed either 1500 mg/l or 150 mg/l attributable to human activities

[5] Does not reduce depth of compensation point for photosynthetic activity by more than 10% from norm.

[6] Based on 0.02 mg/l un-ionized NH_3 with PH = 7.5, T = 25°C.

[7] Based on 0.05 mg/l un-ionized NH_3 with PH = 7.5, T = 25°C.

[8] 0.100 for irrigation

[9] Standard (mg/l)

soft water	hard water	type of aquatic life
0.0004	0.0012	cladocerans, salmonid fish
0.004	0.012	less sensitive aquatic life

[10] As hexavelent Cr

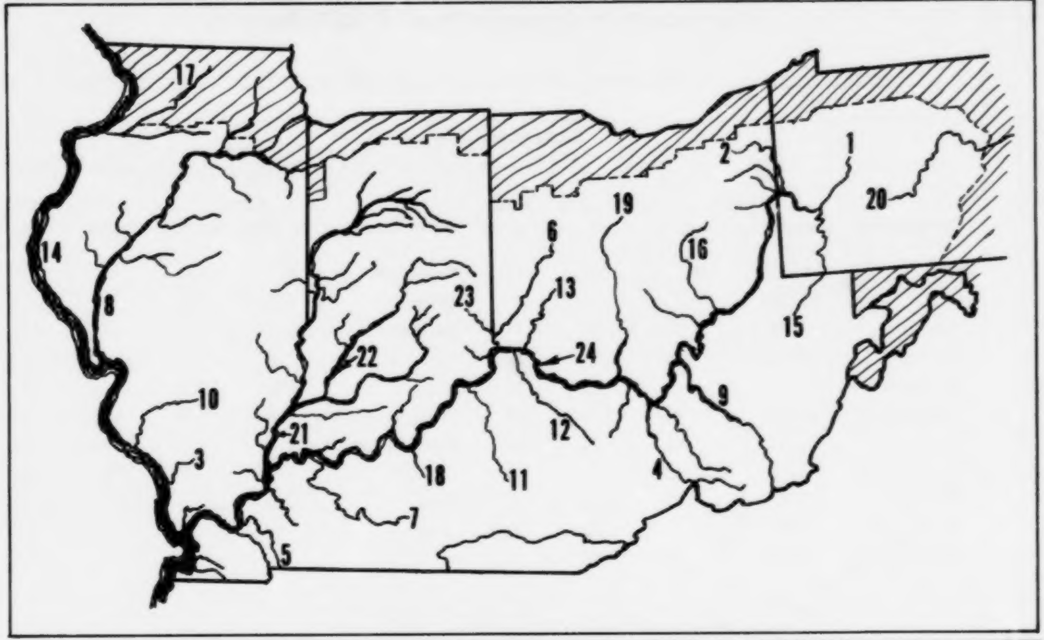
[11] Based on total hardness = 260-280 mg/l as $CaCO_3$ and 0.1 (96 LC_{50}) if Cu and 0.01 (96 LC_{50}) if Zn

[12] 0.75 for irrigation on sensitive crops

In the late summer under 7-day-10-year low flow conditions, navigable pools on the Ohio River main stem experience temperatures of 86 degrees Fahrenheit, which is 2 degrees above the temperature used by ORBES as a reference standard. Dissolved oxygen levels at this time drop below 5 milligrams per liter, the level used in the study as a reference necessary to maintain a system's balance.

Pollutant Sources. The sources of these pollutants that are in violation of the study's reference concentrations during 7-day-10-year low flow vary

Figure 4-12
ORBES—Region Rivers Selected for Detailed Analysis


17
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RIVER	MAP NO.	RIVER	MAP NO.
Allegheny	1	Little Miami	13
Beaver	2	Mississippi	14
Big Muddy	3	Monongahela	15
Big Sandy	4	Muskingum	16
Cumberland	5	Rock	17
Great Miami	6	Salt	18
Green	7	Scioto	19
Illinois	8	Susquehanna	20
Kanawha	9	Wabash	21
Kaskaskia	10	White	22
Kentucky	11	Whitewater	23
Licking	12	Ohio Main Stem	24

Table 4-2
Rivers Studied in Detail: Protection Levels, Number of Reaches, Pollutants Violating ORBES Reference Concentrations at 7-day–10-Year Low Flow, and Flow per Second at 7-Day–10-Year Low Flow

River	Protection Level	Number of Reaches	TDS	TSS	SO_4	NH_3	AS	Ba	Cd	Cl	Cr	P	Se	Ag	Cu	Fe	Pb	Mn	Hg	Ni	Zn	B	7-Day–10-Year Low Flow (cfs)
Allegheny	A	4	•				•				•	•				•	•	•	•				470–1098
Beaver	B	2				•					•	•		•	•	•		•	•		•		86–232
Big Muddy	A	1										•				•		•					37
Big Sandy	A	2		•							•	•			•	•	•	•	•	•		•	26–59
Cumberland	A	3							•			•		•		•		•	•				8–4100
Great Miami	A	4		•					•		•	•		•	•	•	•	•	•		•		58–281
Green	A	2		•							•	•		•		•	•	•	•				306–500
Illinois	A	9				•						•			•	•	•	•	•				451–3601
Kanawha	A	2									•	•				•	•	•	•	•			1106–1285
Kaskaskia	A	1										•				•		•					100
Kentucky	A	3																					113–164
Licking	A	1		•							•	•	•		•	•		•	•				10
Little Miami	B	1		•					•		•	•			•	•	•	•	•				27
Mississippi	A	7										•			•	•		•	•				15, 752–47, 412
Monongahela	A	3									•	•				•		•	•	•			384–459
Muskingum	B	2		•					•		•	•		•		•	•	•	•				551–566
Ohio Main Stem	A	32		•					•		•	•		•	•	•	•	•	•	•			6558–45, 421
Rock	B	1																					1306
Salt	A	1																					20
Scioto	A	4		•		•					•	•	•	•		•	•	•	•				48–337
Susquehanna	A	1																					136
Wabash	A	10		•								•			•	•			•	•			130–2498
White	B	6		•		•						•			•	•		•	•				155–685
Whitewater	B	1		•								•											82

• Violates ORBES reference concentration at 7-day–10-year low flow

Table 4-3
Aquatic Habitat Impacts on Rivers Studied in Detail, 7-Day–10-Year Low Flow

River	1976 Protection Levels (normal flow)	Water Quality Impact Index (range: 0 to 100)	1976 Protection Levels (7-day–10-year low flow)	1976 Aquatic Habitat Impacts(7-day–10-year low flow)
Allegheny	A	26	C	Heavy
Beaver	B	30	C	Heavy
Big Muddy	A	15	B	Moderate
Big Sandy	A	39	C	Heavy
Cumberland	A	30	C	Heavy
Great Miami	A	47	C	Heavy
Green	A	38	C	Heavy
Illinois	A	15	B	Moderate
Kanawha	A	31	C	Heavy
Kaskaskia	A	15	B	Moderate
Kentucky	A	—	*	—
Licking	A	30	C	Heavy
Little Miami	B	45	D	Heavy
Mississippi	A	18	B	Moderate
Monongahela	A	30	C	Heavy
Muskingum	B	38	C	Heavy
Ohio River Main Stem	A	40	C	Heavy
Rock	B	—	*	—
Salt	A	—	*	—
Scioto	A	35	C	Heavy
Susquehanna	A	—	*	—
Wabash	A	20	B	Moderate
White	B	30	D	Heavy
Whitewater	B	—	*	—

*Background data incomplete; analysis could not be conducted.

according to the type of waterway. In general, nonpoint sources--such as agricultural and urban storm runoff--account for the majority of the 1976 concentrations. Navigable waterways draining into the Ohio carry primarily industrial and organic pollutants, while those draining into the Mississippi carry primarily agricultural pollutants. Habitats along the smaller tributaries, on the other hand, are affected primarily by siltation (sediment deposits) and stream desiccation (drying)--mostly from farming and mining rather than from industrial development. In particular, orphan-mined (abandoned) land in both the Appalachian and Eastern Interior coal provinces is the major source of water quality problems for many ORBES-region tributaries. However, some tributaries do receive substantial quantities of organic waste, and a few small streams and many of the small accidental lakes created by surface mining and rainfall are threatened directly by acid mine drainage.

AQUATIC HABITAT IMPACTS. The projected aquatic habitat impacts that would occur under 7-day-10-year low flow as a result of the projected 1976 low flow concentrations appear in table 4-3. This table indicates (1) any changes in a stream's protection level, (2) the water quality index value, and (3) the resulting aquatic habitat impacts. The water quality index is based on violations in water quality parameters and is weighted according to those violations.[24]

In table 4-3, a water quality index value of less than 10 percent of the maximum possible impact (a value of 100) represents light impacts. Under these conditions, impacts on a system's biota probably would not be detectable except locally in the vicinity of outfalls. No change in a stream's protection level would be expected to occur.

Moderate impacts are projected based on a water quality index equal to or greater than 10 percent but less than 25 percent of the maximum possible impact. Under these conditions, minor eutrophication with some loss of existing embryonic fishes would be expected.[25] The effects would be noticeable at low flow, but recovery over the next several seasons also could be expected. A stream's protection level would drop one level during the period of recovery.

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[24] For a further discussion of this index and of the projected aquatic habitat impacts, see Leuthart and Spencer, Fish Resources and Aquatic Habitat Impact Assessment Methodology.

[25] Eutrophication--the enrichment of natural waters with soluble nutrients--often results in the formation of a bacterial growth medium with the subsequent depletion of dissolved oxygen required for fish and aquatic life.

A water quality index equal to or greater than 25 percent but less than 50 percent of the maximum possible impact represents heavy impacts. Under these conditions, eutrophication, a concentration of heavy metals, and possible stream desiccation would combine to have a marked effect on the stream's biota. The effects would be immediately noticeable with local fish kills. A longer period of recovery, possibly five to seven years, would be required. A stream's protection level would drop two levels for a minimum of five years.

Drastic impacts would occur when the water quality index is equal to or greater than 50 percent of the maximum possible impact. Under these conditions, eutrophication, a concentration of heavy metal salts, dissolved oxygen depletion, siltation, and stream desiccation would combine to essentially destroy the existing system. Extensive fish kills would be expected all along the waterway, with nearly complete loss of embryonic fishes. The period of recovery might range up to 20 years, depending on the final condition of the watershed or the steps taken to recover it. A stream's protection level would drop three levels for at least 15 years.

As table 4-3 indicates, the majority of the region's largest streams would have experienced significant aquatic habitat impacts in 1976 under 7-day-10-year low flow conditions, primarily because total water consumption would have concentrated the high background pollutant levels to levels intolerable to many fish species.

4.6 Health

In general, the ORBES region has a worse health status (as measured by the age-adjusted death rate) than does the nation. Moreover, some of the ORBES states that exhibit high mortality rates or that account for most of the regional or national coal-processing deaths and disabling injuries tend to rank low in health services.

In this section the health status of the region is delineated, and regional health services are described. Estimates also are made of the deaths and diseases attributable in 1976 to the use of coal for electrical generation in the ORBES region. Finally, the potential health problems associated with regional nuclear-generated electricity and with electrical transmission are characterized.[26]

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[26] This discussion of public and occupational health in the region is based on the following ORBES Phase II reports: Edward P. Radford, Impacts on Human Health from the Coal and Nuclear Fuel Cycles and Other Technologies Associated with Electric Power Generation; Maurice A. Shapiro and A.A. Sooky, Ohio River Basin Energy Study: Health Aspects; and Symposium on Energy and Human Health: Human Costs of Electric Power Generation.

HEALTH STATUS. During the 25 years prior to the base period, each of the six ORBES states (with the exception of Ohio in the early 1950s) exhibited age-adjusted death rates higher than the national rate.[27] In 1975, Indiana had the lowest rate in the ORBES region (705.6 deaths per 100,000 persons), while West Virginia had the highest rate (772.2 deaths per 100,000 persons). In the same year, the national average was 692.9.

Five indicators of health status were selected and analyzed statistically at the county level to identify areas of health difficulty in the region. These indicators are (1) age-adjusted death rates for all causes, (2) age-adjusted respiratory cancer (lung, trachea, and bronchus) mortality for white females, (3) the same cancer mortality for white males, (4) infant mortality rates, and (5) the percentage of total deaths due to ischemic heart disease. (Ischemia is disability due to reduced or suppressed blood supply.)

Of the six ORBES state portions, Kentucky and West Virginia display the highest concentration of counties with high age-adjusted mortality rates, high infant mortality rates, and high female respiratory cancer mortality rates. However, Kentucky also exhibits a high concentration of counties with low male respiratory rates and low ischemic heart disease mortality rates. As a result, when individual death rate statistics are used to calculate a health status index for each ORBES county, Kentucky is the state with the greatest percentage of counties with high health status index values. West Virginia, on the other hand, is the state with the greatest percentage of counties with a low (unhealthy) index. Of the four remaining ORBES state portions, Illinois displays a very high concentration of counties with high ischemic heart disease mortality rates.

HEALTH SERVICES. To complement the health status information, health services in the ORBES region also were surveyed, and a county-by-county ranking of health service availability was performed. While there is some problem in equating health service availability with equity of access or improved health status as well as in equating health manpower with availability, health service indices were constructed to permit comparisons to be made among the ORBES county rankings.[28]

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[27] For a discussion of the region's health status, see Shapiro and Sooky, Ohio River Basin Energy Study: Health Aspects.

[28] For a discussion of the limitations of the health availability concept, of the data used, of its limitations, and for county-by-county tables, see Shapiro and Sooky, Ohio River Basin Energy Study: Health Aspects. Indices for individual categories--such as physicians, nurses, and pharmacists--also are given in this report.

For the most part, health service availability is directly correlated with population: high-population counties rank higher in health service availability than do counties with low populations. Mapping of this trend frequently illustrates that such counties are often in close proximity--that is, larger metropolitan counties are ranked high while immediately surrounding or nearby counties are ranked low. Counties in the lowest tenth of the health service availability ranking tend to be located south of the Ohio River throughout the states of Kentucky and West Virginia, where counties usually are less populated and/or are in or near mountainous areas. In fact, a high concentration of low availability counties was noted in northeastern Kentucky and northcentral West Virginia. In contrast, there is a high concentration of counties with high health service availability rates in western Pennsylvania.

COAL-RELATED IMPACTS. The use of coal for electrical generation by utilities results in potential health impacts in the ORBES region. These impacts are related to the five steps of the coal fuel cycle: coal mining, coal processing, coal transport, coal conversion, and waste disposal. In general, projections of accidental injuries and deaths are built upon current knowledge of cause-and-effect relationships. However, the health consequences of chronic, relatively low-level exposure to several environmental contaminants remain a matter of some controversy.

Coal Mining. The occupational health impacts related to mining are fairly easy to document, primarily because annual data are kept nationally on mining-related deaths, injuries, and disabilities. Nevertheless, variations exist in the number of coal-related deaths, injuries, and diseases that have been specifically attributed in the literature to coal demand by power plants.[29] In this study, rates were derived for the ORBES region based on the 1975 state coal-mining fatalities, injuries, and disabilities, on the 1975 coal purchases by ORBES power plants, and on the 1975 state distributions of underground and surface mining.[30] The number of coal-mining deaths, injuries, and disabilities attributable in 1975 to ORBES power plant coal demand are as follows: 37 accidental deaths, 2656 disabling injuries, 2198 nondisabling injuries, 6 disease deaths, and 284 disease disabilities (including 13 to 51 new cases of disabling pneumoconiosis).

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[29] For calculation of rates and a discussion of the ranges that exist in the literature, see Shapiro and Sooky, Ohio River Basin Energy Study: Health Aspects.

[30] See Shapiro and Sooky, Ohio River Basin Energy Study: Health Aspects. Because calculations were based on annual purchases, some of which are from outside the region, a small portion of these health impacts (about 2 to 3 percent) occur outside of the region.

The long-term health impacts of coal mining on the general public are not well understood, especially since some of the effects created by coal mining--such as fugitive dust and abandoned mine fires--are episodic, localized, and the result of past mining practices. Therefore, it is not possible at this time to quantify the health impacts of these effects.

Coal Processing. The primary function of coal cleaning and processing is to supply a feedstock that satisfies the physical and chemical specifications required for final use. About 50 percent of the total coal output in the ORBES region is mechanically cleaned and about 5.8 percent is thermally dried.

Health impacts from coal processing in the ORBES region include injuries to cleaning plant personnel as well as indirect impacts from the release into water of toxic trace metals from generated residuals. The first group of impacts has been quantified and recorded for the past sixty years. The second group of impacts, however, is extremely difficult to quantify due to many site-specific modifying factors.

Data for the period 1972 through 1976 indicate that a yearly average of 3 fatalities and 198 disabling injuries were associated with coal processing for ORBES-region power plants.[31] It should be noted, however, that in some years the ORBES region sometimes accounts for a majority of the deaths and injuries reported nationally for coal cleaning by mechanical plants. For example, all of the 1974 and 1976 fatalities reported at mechanical coal-cleaning plants occurred in the study region, and the disabling injuries included in the statistics were reported mainly in ORBES-region plants. Within the region, three ORBES states--Kentucky, Pennsylvania, and West Virginia--consistently account for most of the fatalities and the major share of the disabling injuries in the study region. (Health aspects due to disease-related deaths and illnesses could not be determined because the effects are not known.)

According to 1976 data, coal processing results nationally in about 100 million tons per year of refuse. Coal wastes contain a broad array of trace or minor elements such as lead, arsenic, mercury, and cadmium. The presence of these elements is of some concern because of their toxicity and because of the low tolerance of plants and animals to them. Coal-processing refuse also is a significant source (about 25 percent of the total from all mining operations) of acid residues, which can leach into water, and is a major source of trace elements in leachates. However, as in the public health impacts of mining, there is as yet no basis for providing quantitative estimates of these public health impacts of coal processing.

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[31] See Shapiro and Sooky, Ohio River Basin Energy Study: Health Aspects, for the method of calculation.

Coal Transportation. Since most of the indirect damage of coal transportation is due to the air pollution generated by the transportation units, and since such damage cannot be quantified at the present time, only accidental injuries and deaths are reported. For the general public, these injuries and deaths are related to railway grade-crossing, switching, and yard accidents as well as to truck collisions on highways.

In the ORBES region, about 68 percent of the coal is shipped by rail; another 14 percent, by barge; and another 12 percent, by truck. The remaining portion is transported by other means or goes directly by conveyor belt to mine-mouth plants. The health impacts associated with coal transportation to ORBES-region power plants are the highest for train transportation and the lowest for barge transportation. However, both train and truck health impacts vary according to whether statistics based on weight transported or miles traveled are used. Thus, there is variation in the estimates of the total deaths and injuries in 1975 attributable to the transportation of coal to ORBES-region power plants. If the miles traveled are used, approximately 12 deaths and 48 injuries are attributable to such demand. If the weight transported is used, approximately 49 deaths and 207 injuries are attributable to such demand. Both occupational and public deaths and injuries are included in these estimates, although deaths are suffered mostly by the public sector while the injuries are fairly evenly divided between the two sectors.[32] In general, if statistics based on the weight transported are used, health damages are relatively high because, compared to most freight, the density of coal is high (except for barges). Assigning health damages based on the miles traveled probably results in a slight underestimate because the heavy weight of coal may lead to greater probability of injury in case of accidents.

Coal Conversion. Substantial controversy exists about the quantification of the morbidity and mortality attributable to the increased air pollution resulting from the burning of coal to produce electricity. New information on the subject continues to be published. The problem becomes increasingly difficult as ambient concentrations are reduced from the high concentrations that prevailed in well-known air pollution episodes. However, a number of conclusions about the current state of knowledge can be drawn. For one, only a few studies prior to 1970 can be relied on to provide any quantitative estimate of risk. This is due primarily to the lack of reliable pollutant measurements and the confounding aspects of personal risks that derive from cigarette smoking and from occupational and indoor exposure. Also, sulfur dioxide, by itself, in concentrations of 500 micrograms per cubic meter or less, has no significant short-term effect on respiratory mechanics, symptoms, or disease.

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[32] For a fuller discussion of the calculations involved and of the differences between ton-miles and vehicle-miles, see Shapiro and Sooky, Ohio River Basin Energy Study: Health Aspects.

Recently it has been possible to relate acute morbidity and mortality from cardiovascular disease, but not respiratory disease, to total suspended particulates in the range of 300 micrograms per cubic meter and higher over a period of several years. Recent studies suggest that particulates in this range are associated in a reasonably dose-related fashion with an increased mortality rate. However, an increased mortality rate is correlated less, if at all, with sulfur dioxide. In addition, there is evidence to support the hypothesis that cardiovascular disease is the principal cause of mortality associated with acute air pollution effects. Unfortunately, the biological mechanisms by which inhalation of airborne particulates influences cardiovascular disease mortality remain obscure.

An analysis of recent data indicates that cardiovascular mortality is increased by 5 percent with sustained, long-term (several years) exposure to airborne particulates at a concentration of about 350 micrograms per cubic meter. If such an increased risk is scaled down to possible annual urban levels (100 micrograms per cubic meter) and then adjusted for the population exposed and the contribution of utility emissions, the maximum number of annual cardiovascular deaths per 1000 megawatt plant is about three. This projection is an upper limit. The lower limit is zero because the defense mechanisms of the body may be able to cope with low-dose exposures without any significant effect on cardiovascular disease.[33]

Other researchers, however, believe that a growing body of evidence supports the hypothesis that the annual average exposure to sulfates--or something closely related to them--results in an increased mortality rate.[34] According to this line of thought, long-term exposure to air pollution, particularly in childhood, increases susceptibility to respiratory infection; a history of repeated respiratory infection, possibly coupled with continued air pollution exposure, then increases the prevalence of chronic respiratory disease, leading to more deaths from a broad range of cardiopulmonary diseases. Based on this sequence, these researchers project annual deaths attributable to sulfate air pollution in terms of damage functions of 0 to 9 deaths per 100,000 persons exposed per microgram per cubic meter. On the basis of a damage function of 3 deaths per such exposure (which is close to the median value of the proposed health damage functions), it can be calculated that 8000 deaths occurred in the ORBES region in 1975 due to sulfate air pollution by ORBES electrical generating facilities--provided that the same conditions would be maintained steady-state for a sufficient number of years to allow full development of the impact. However, the possibility exists that the attributable 1975 mortality is as low as zero or as high as 25,000. The figure of 8000 yearly deaths constitutes about 3.6 percent of the total 1975 mortality in the ORBES region.

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[33] See Shapiro and Sooky, Ohio River Basin Energy Study: Health Aspects, and Radford, Impacts on Human Health.

[34] See Leonard D. Hamilton, "Areas of Uncertainty in Estimates of Health Risks" in Symposium on Energy and Human Health. For disagreement with this approach, see Radford, Impacts on Human Health. For a discussion of both sides, see Shapiro and Sooky, Ohio River Basin Energy Study: Health Aspects.

The fact that this sulfate damage figure is nearly 40 times higher than the cardiovascular-particulate damage figure points up the current uncertainty in estimating a relevant damage function. Thus, while these quantitative estimates of health impacts are helpful in grasping the magnitude of the impact, they must be considered in light of unquantified potential effects of air pollution and in light of other uncertainties in the many related factors, such as background levels, time distribution of induced deaths, and the variability in individual responses to air pollutants. The major usefulness of the damage function for the ORBES study lies not in the accuracy of the estimated health impacts but in the comparison of the impacts between the various scenarios.

Occupational injuries among workers at coal-fired plants average about 0.02 fatalities per year per 1000 megawatts and about 1.2 disabling injuries per year per 1000 megawatts.[35] In terms of occupational disease among such workers, the same controversy about the quantification of morbidity and mortality exists as outlined in the last two paragraphs.

Waste Disposal. As yet no evidence exists of public health impacts related to waste disposal, although the potential exists for the leaching of potentially hazardous wastes from storage areas into water supplies. The possibility of workers' exposure to fugitive dusts from waste storage also exists, but the potential effects of such exposure are unknown.

NUCLEAR IMPACTS. There are nine possible steps in the nuclear fuel cycle: mining, milling, conversion, enrichment, fuel fabrication, power generation, reprocessing, waste management, and transport. However, not all of these steps are currently carried out in the ORBES region or in the nation. Within the ORBES region, only the uranium enrichment, the fuel fabrication, and the power generation steps take place at present.[36] Assuming a single year of exposure, three steps in the nuclear cycle--the mining, milling, and power generation steps--are expected to result in a total incidence of lifetime cancers among the general public of between 0.03 and 0.05 cases per year per 1000 megawatts electric of nuclear power production.[37] Roughly half of these cases would be associated with the power generation step. In 1976 in the ORBES region, 10 million megawatts were produced by nuclear-fueled power plants. Thus, between 150 and 250 cases of cancer are expected to have occurred in 1976 because of nuclear power generation. (No attempt was made in this study to quantify possible genetic effects from accidental releases.)

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[35] For a discussion of these rates, see Radford, Impacts on Human Health.

Occupational health effects related to the nuclear fuel cycle can be presented with more certainty than can those for the general population. However, neither possible genetic effects nor the risks from accidental releases were quantified for workers.

The whole-body annual exposure of all workers--but primarily those in the power generation step--results in about 0.2 to 0.8 excess lifetime cancers per year for each 1000 megawatts of electricity generated. For miners, millers, and fuel fabrication workers, who receive significant lung doses from alpha radiation, additional lung cancers will occur from this exposure--about 1.3 excess lung cancers from a year's exposure. Thus, the total lifetime excess cancers arising from annual occupational exposures in the nuclear fuel cycle range from 1.5 to 2.1 per year for each 1000 megawatts generated. Other occupational health impacts were examined, and the following rates per 1000 megawatts generated were projected: a 2.0 trauma rate, an 0.5 silicosis rate, and an 0.5 chronic lung disease rate.

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[36] For a full discussion of all of the steps in the nuclear fuel cycle--some of which have much severer health impacts than indicated for the ORBES region--see Radford, Impacts on Human Health. See also Steven D. Jansen et al., Nuclear Energy Risks and Benefits (ORBES Phase II). Estimates in the Radford report are derived from the March 1979 draft report of the Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR Committee), U.S. National Academy of Science.

[37] For each 1000 megawatts of nuclear-fueled electricity generated each year, the following exposure rates were assumed. For the general public, the whole-body total exposure (measured in person-rems) is less than 1 for the enrichment and fabrication steps and 20 for the power generation steps; individual maximum exposures (measured in rems per year) are 0.006 (lung) for the enrichment step, 0.005 (lung) for the fabrication step, and 0.01 (thyroid) for the power generation step. The number of workers exposed each year was assumed to be about 500 for the enrichment step and about the same number for the fabrication step; for the power generation step, about 800 workers were assumed to be exposed each year. The whole-body total exposure for these workers is 25 for the enrichment step, 100 for the fabrication step, and 800 for the power generation step. Individual occupational average exposures (rems per year) are 0.05 (whole body) for the enrichment step; 10 (lung) and 0.2 (whole body) for the fabrication step; and 1.0 (whole body) for the power generation step. See Radford, Impacts on Human Health.

ELECTRICAL TRANSMISSION IMPACTS. One final area of potential health effects related to electrical generation involves the transmission of electricity.[38] Possible risks to both the general public and power line workers include the effects of electric and magnetic fields, the effects of corona around transmission lines, and accidental injuries and deaths from fallen or broken transmission lines. Occupational risks also include the risks associated with direct contact with high-voltage terminals or other low-resistance pathways.

In studies to date, no general public health effects from transmission lines have been demonstrated other than those resulting from accidents involving fallen or broken lines. Besides accidental deaths and injuries, the same statement is true for persons employed in transmitting electricity. However, many of the studies tend to examine short-term effects. Studies on long-term effects would give a better understanding of the risks involved in this phase of electrical generation.

4.7 Social Conditions

Basic social measurements of population, schooling, employment, housing, and income trends indicate that in many respects the ORBES region is quite different from the United States as a whole.[39] For example, regional population is growing at a slower rate than is national population, and housing prices are lower in the region than in the nation. In general, the region is one of contrasts. It contains heavily industrialized metropolitan areas; intensively farmed, low-population sections; and extensive portions with low population and only minimal economic activity.[40]

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[38] For a discussion on the health impacts of electrical transmission, see Radford, Impacts on Human Health.

[39] The most recent data were used for each of the social measurements discussed in this section. In some cases, however, data from 1970 constituted the only available information. It is recognized that updated information could change some of the conclusions in this section.

[40] For details on current social indicators in the study region, see the following ORBES Phase I reports: Preliminary Technology Assessment Report

In 1977, the ORBES region had 23.7 million inhabitants, about 11 percent of the 1977 U.S. population of 216.4 million. The ORBES state portion of Ohio accounted for most (31 percent) of this 1977 regional population (see figure 4-13 for the contributions of the other state portions).

If both crude death and birth rates in 1977 are considered, it appears that there is a smaller rate of natural population increase in the region than in the nation as a whole.[41] The crude birth rate in the ORBES region in 1977 was only slightly higher (about 1 percent) than in the nation in that year, while the crude death rate in the ORBES region in 1977 was considerably higher (12.5 percent) than in the nation. However, fertility rates in the ORBES region have usually been lower than in the nation as a whole. In 1960 and 1970, for example, fertility rates (measured in the lifetime number of births per woman) in the region were 4.1 percent and 2.6 percent lower, respectively, than were national rates. Between 1970 and 1978, regional population grew by about 750,000 persons due to natural increase. During this period, however, more persons left the ORBES region than entered the area; the total number of persons who left the region was approximately 352,000.

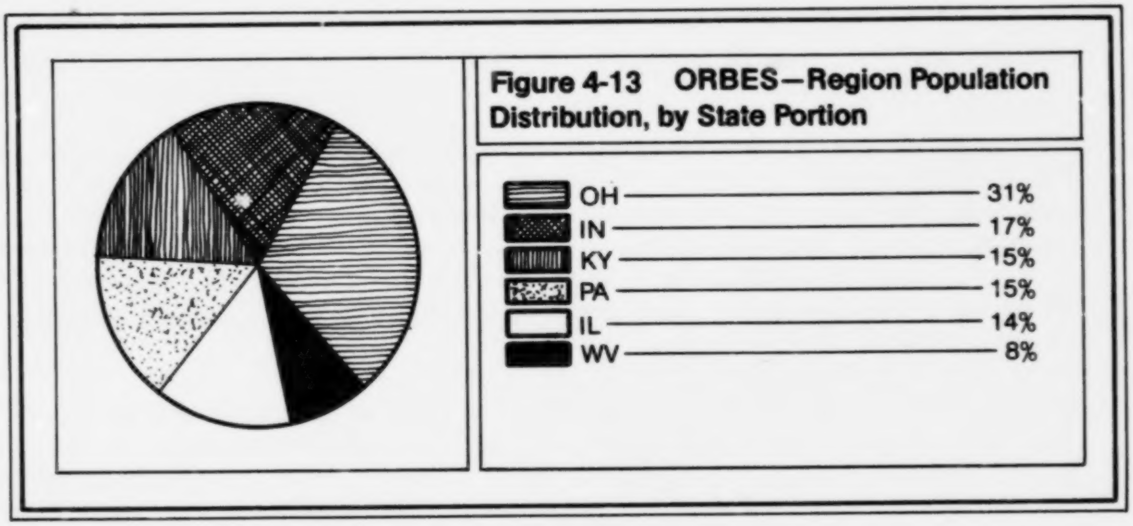

Figure 4-13 ORBES—Region Population Distribution, by State Portion

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vols. II-a, II-B, and II-C. See also James J. Stukel and Boyd R. Keenan, ORBES Phase I: Interim Findings. The following ORBES Phase II reports provide further details: Vincent P. Cardi, ed., West Virginia Baseline; Maurice A. Shapiro, ed., Pennsylvania Baseline; and David S. Walls et al., A Baseline Assessment of Coal Industry Structure in the Ohio River Basin Energy Study Region.

[41] Crude death and birth rates are gross rates; that is, they have not been adjusted for age or any other variation.

EDUCATION. The regional population has less education than the national population. In 1970, the average schooling in the region was 9.7 years per person, compared with 12.2 years in the United States as a whole.

EMPLOYMENT. In 1970 the ORBES workforce (the number of employed persons) totaled about 8.8 million. The regional unemployment rate was about 5.8 percent, compared with the national rate of 5.4 percent in that year. The average number of employees per county in 1970 was about 20,000. About 3 percent of the 1970 workforce (276,000 persons) was employed in agriculture. Among the ORBES state portions, Illinois accounted for the most agricultural employment in 1970 (about 29 percent of the regional total). The Indiana state portion accounted for about 20 percent; the Kentucky portion, for 25 percent; the Ohio portion, for 19 percent; the Pennsylvania portion, for 4.8 percent; and the West Virginia portion, for 2.5 percent.

In 1977 in the ORBES region, about 28 percent of the workforce (2.5 million people) was employed in manufacturing. Among the six state portions in 1977, Ohio accounted for most of the manufacturing employment (about 36 percent of the regional total). The Indiana state portion accounted for 20.7 percent of the regional total; the Pennsylvania portion, for 14.9 percent; the Illinois portion, for 12 percent; the Kentucky portion, for 11.3 percent; and the West Virginia portion, for 5.1 percent.

About 2 percent of ORBES-region inhabitants (or 212,000 people) were employed in mining in 1977. Among the ORBES state portions, West Virginia accounted for most of the coal-mining employment (about 32 percent of the regional total), followed by Kentucky (22 percent), Pennsylvania (19 percent), Ohio (11 percent), Illinois (11 percent), and Indiana (4 percent). The ORBES-region mining workforce in 1977 represented about 80 percent of all U.S. miners.

HOUSING. In general, housing rates (prices for both rental and purchase) in the ORBES region are lower than in the rest of the nation. In 1970, the average of the median rental among the six ORBES state portions was $85 per month, with a range of $40 to $130 among all ORBES counties. In the nation in 1970, the median rental was $89 per month.

In both the ORBES region and the United States, areas with fewer new units and more older units could experience housing problems with an increase in population since a higher proportion of older units indicates a relatively inactive housing construction industry. In the ORBES region, 48.7 percent of the housing was built before 1939; the comparable figure for the nation is 40.6 percent. Within the region, 22.3 percent of the housing was built after 1959; in the nation, 24.7 percent was built after that year.

INCOME. Income is another key social indicator. Compared to the U.S. median income, median income in the ORBES region is low, due in large measure to a number of poverty pockets. Across all ORBES counties, the median family income in 1970 was $7672, with a range among these counties of $11,694 to $2407. The median U.S. family income in 1970 was $10,480. However, per capita income is only slightly different in the nation and the region. In 1975, for example, average regional per capita income was $4517; average national per capita income, $4572. On the other hand, the region has a higher percentage of families below the poverty level than does the nation. In 1970, 16 percent of the families in the ORBES region were below the poverty level. In comparison, about 11 percent of families in the nation were below the poverty level in that year. Among the 423 ORBES counties, the proportion of families below the poverty level ranged from 2.4 to 61.6 percent of the families in each of these counties.

4.8 Social Values

A secondary analysis of studies conducted in the six ORBES states between 1974 and 1979 indicates how the values held by the residents of these states relate to energy policy.[42] In this analysis, seven key values were examined as they relate to the residents' responses about energy. These values are conservation/preservation, economic benefit, equity, freedom and government activity, progress/growth,[43] health/safety, and material comfort.

Conservation/preservation implies "doing more with less"; the objective is to use more energy-efficient technologies to produce the same output of goods, or simply to use or produce less energy, with resulting changes in lifestyle. Economic benefit refers to the tendency to evaluate things and people in monetary terms, and equity is the degree of fairness and social justice associated with the distribution of costs and benefits. Freedom and government activity are discussed here not as separate values, but as opposite ends of a continuum. Freedom refers to allowing a person maximum choices, with only limited control by others over what the individual may do; the control operates through group norms rather than formal laws. In contrast, government activity is intervention by government to facilitate, inhibit, or regulate certain decisions and actions through policies and legislation. Progress/growth is an important value with respect to energy development because it emphasizes the future rather than the past or present; a receptivity to change is implied, as well as a belief that things in general can and should be made better. The value of health/safety implies giving high priority to citizens' health and to devoting resources to ensure good health for as many people as possible; it also includes the desire for healthful and safe surroundings. Material comfort involves an orientation toward the acquisition of goods and/or the concept that self-esteem is linked to material worth.

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[42] Illinois data were available for the ORBES portion of the state; Pennsylvania data, for counties in the southwestern part of the state. For the four other ORBES states, data were statewide. See Harry R. Potter and Heather Norville, Ohio River Basin Energy Study: Social Values and Energy Policy (ORBES Phase II).

[43] The separate concepts of progress and growth were grouped for this analysis; it is recognized that they are not necessarily identical. However, many definitions of progress imply economic growth and increased material accumulation.

In general, it appears that in the region, as in the nation as a whole, no one value has predominant importance over all others. Rather, people strive to achieve a balance between competing values when confronted with difficult choices. The analysis also suggests that when people are asked to choose among energy policies, they do not necessarily choose those that would be in their own self-interest. For example, although the majority may favor policies that provide financial rewards for insulation and oppose policies that would increase fuel taxes, they also may favor conservation policies and equity even though these may lead to increased costs. In addition, although people may express verbal support of a certain action in response to survey questions, their actual behavior may not match their stated willingness.

CONSERVATION/PRESERVATION. The responses that seem to stress conservation/preservation as a value begin to demonstrate some of these complexities. Studies in the six ORBES states and the nation have found a high degree of willingness among respondents (ranging from 55 to 95 percent) to engage in such conservation/preservation practices as recycling, traveling less, turning down the heat in winter, improving home insulation, and using fewer electrical appliances. However, support for government activity aimed at achieving conservation/preservation appears to vary.

In general, the analysis shows that respondents support government policies aimed at achieving conservation through positive rewards for conservation. But they oppose policies that have negative sanctions for not conserving, such as rationing and higher fuel prices. Similarly, support for conservation/preservation is divided when the values of freedom, material comfort, or economic benefit are seriously threatened. For example, a 1975 Kentucky study showed a majority of the respondents (53 percent) were opposed to regulations that would ensure that people use less fuel. Yet, in the same study, a majority of the respondents (71 percent) favored stricter regulations that would require industries to use less fuel. However, a majority also expressed support for policies that would preserve the environment even though such policies would cost them money; 85 percent favored stricter regulations requiring industries to pollute less even though products might cost more.

Support or opposition for a government policy that encourages conservation also can vary according to income, race, and other variables. For example, in a national study, unlike the majority in the Kentucky study, a slight majority of respondents with incomes below $7000, a slight majority of blacks, and a slight majority of farmers favored a policy whereby the government would ration family energy consumption and the family would decide how to apportion its use.

Similar differences related to age, sex, income, and education can be found in the ORBES states when people are asked about what they are doing to conserve energy. In a 1978 Illinois study, the respondents with higher incomes were more selective in their conservation practices; like other people they tended to conserve energy for heating and air conditioning, but they indicated that they were much less likely to live in a smaller house or to use appliances less. In the same study, female respondents were more likely to say they were conserving than males. Also in the Illinois study, older persons were as likely as younger people to approve home insulation. Unlike the same group nationwide, more older persons in the Illinois survey reported that they were using fewer appliances and living in a small house or apartment to conserve energy.

ECONOMIC BENEFIT. As the Kentucky study referred to above begins to suggest, and as data from other states and the nation support, the economic benefit of a situation is important, although it is not the single criterion people use in choosing among policies. Most of the available data are based on tradeoffs between this value and others. In many instances, respondents are willing to endorse certain costs when the choice is posed against other values, such as government activity, health/safety, and conservation/preservation. Thus, 85 percent of the Kentucky respondents supported government control of industrial pollution even if the prices of products were to rise, and 85 percent also expressed strong support for more government spending to develop new energy sources.

EQUITY. Equity also has varied support as a value within the region. Although data on equity as a value are limited, they indicate that social class factors and age relate quite consistently to views on equity issues. Data also indicate support for policies that would help compensate the poor or elderly for added energy costs due to policies designed to conserve energy through increased prices, such as price deregulation.

In a 1978 Illinois study, 63 percent of the respondents were willing to see tax money spent to help pay the heating bills of low-income people. However, a closer look at these responses shows that those with less education and lower incomes, as well as older respondents, place greater stress on equity than those with college degrees and higher incomes or than younger respondents. For example, about 74 percent of the respondents with annual incomes below $9000 favored spending tax money to help low-income people with heating bills, compared with only 51 percent with incomes of $25,000 to $39,999 and 43 percent with annual incomes of $40,000 or more. In the same study, older people favored the "equity" answer (that is, providing tax dollars to low-income people) more than younger people did. These responses appear to be very similar to nationwide attitudes.

Equity as a value also is supported when it benefits those whose efforts have been largely responsible for the potential benefits. Thus, enforcement of a policy returning the coal severance tax to coal-producing counties is favored strongly by Kentuckians (82 percent of those surveyed), with only small variations across the social and demographic factors studied.

FREEDOM AND GOVERNMENT ACTIVITY. As some of the above responses to governmental policies suggest, respondents value both freedom and governmental activity. Of particular importance for policy choices is the respondents' tendency to support government activity strongly when it provides direct benefits to people, not to industry. An example of such a tendency is the Kentucky respondents' opposition to regulation of consumer fuel use and their support for regulation of industrial fuel use. Similarly, a 1978 study in Ohio found a majority of the respondents (65 percent) opposed to deregulation of natural gas because it would lead to major cost increases.

However, there can be substantial regional variation, as well as variation by social class, on support of the use of tax dollars to attract new industry to respondents' areas. In 1975, most Kentucky respondents who resided in rural areas and towns with populations under 10,000 favored using more tax money for this purpose, compared with only about one-third of those in the larger urban areas in the state. In Illinois the older respondents were more likely to favor the use of tax dollars to attract new industry, although 73 percent overall were willing to see tax dollars used for such a purpose.

Support for government activity also seems to be strong when it promotes equity, progress/growth, and health/safety. As noted, Kentucky respondents favored government regulations to curb pollution, and Illinois respondents favored the use of tax dollars to help the disadvantaged with added energy costs.

State and national studies thus show people can be quite divided with regard to the role government should play in conserving energy or in developing new sources of energy. For example, in both state and national studies, some groups, such as farmers, consistently favored voluntary action rather than government-mandated action with regard to energy policy.

PROGRESS/GROWTH. As both the varied support for governmental encouragement of new industries and the varied support for governmental encouragement of new energy sources suggest, support for progress/growth as a value can be varied. In general, a positive attitude toward progress/growth is shown quite frequently through the need many people express for new jobs and new industry, often naming the lack of available employment opportunities as the most frequent community problem. However, substantial concern also is indicated at times for the environmental and inflationary effects of growth. The data thus suggest that ORBES-region residents tend to value progress/growth selectively, favoring it under certain conditions and opposing it under others.

HEALTH/SAFETY. Even though many ORBES-region residents may favor new industry and new energy sources under some circumstances, they do not accept such development without qualification when associated risks to health and safety are present. Both regionally and nationally, health/safety is of major importance. Nationally, a majority of respondents indicate strong concern about the effects on health and safety of industrial installations and power plants (both coal fired and nuclear fueled). A majority also were willing to pay $30 more per year to cut down on air pollution caused by power plants.

MATERIAL COMFORT. Respondents in both the region and the nation also rank material comfort as an important component of their lives. Nationally, the majority of Americans surveyed (71 percent) felt that allowing the mass of people to share a high standard of living was a major factor in making the nation great. However, people are willing to trade material comfort for economic benefit. For example, the majority surveyed (76 percent) preferred lowering the heat in their homes to paying $70 more per year for fuel.

In the ORBES region, views on material comfort vary with income and education--just as have the views on many of the other values discussed. In Illinois and Kentucky, for example, those with more education have expressed more willingness to lower their thermostats in the winter than the same group has in the nation. Similarly, in both Illinois and Kentucky, about 70 percent of those with less than a high school education and three-fourths of those with low to modest incomes (less than $10,000 per year) have reported that they are willing to move to smaller quarters, while only 50 percent in Illinois and 60 percent in Kentucky with a high school education or more, and less than half in both states with incomes of $20,000 or more, have expressed willingness to do the same.

COAL-DOMINATED FUTURES

As documented in previous chapters, the Ohio River Basin Energy Study region is heavily concentrated in the use of coal for electrical generation. This condition is unlikely to change during the remainder of this century. Therefore, the regional energy-environmental futures, or scenarios, chosen for the most detailed impact analysis stress the continued use of coal for electrical generation.

All ORBES scenarios are derived from an array of policy assumptions about various conditions in the study region from the base period (the mid-1970s) through the year 2000. These assumptions, plus data on current conditions and the results of various scenario models, are the basis for construction of the scenarios themselves. Each scenario analyzed is characterized in terms of basic policy assumptions, exogeneous variables (such as the growth in the demand for electricity), energy and fuel use, siting patterns for electrical generating units, sources of coal supply, and underlying dominant social attitudes.

The basic scenario with which all other scenarios are contrasted is termed the base case. The conditions assumed in the base case are comparable to but not projections of current conditions in the ORBES region. For example, fuel use patterns and energy growth rates reflect a range of plausible futures, but they are not simple extrapolations of historical trends. Impacts of the base case in the year 2000 are compared with current conditions in the region, while impacts of the four other coal-dominated scenarios are compared with those of the base case. These latter scenarios are the strict environmental control case, the SIP noncompliance case, the high electrical energy growth case, and the electrical exports case. The coal-dominated futures are described in chapter 5.

Five major impact areas are considered for each scenario: air, land, water, employment, and health. In chapter 6, these impacts are compared across scenarios. Impacts of each scenario then receive detailed treatment. First, impacts of the base case are compared with current conditions (chapter 7). Impacts of the remaining coal-dominated futures then are compared with base case impacts: the strict environmental control case in chapter 8, the SIP noncompliance case in chapter 9, the high electrical energy growth case in chapter 10, and the electrical export case in chapter 11.

The analysis of these coal-dominated futures reveals that the changes in air quality would have the most wide-ranging impacts under the various policies examined. In chapter 12, a number of technical and organizational strategies to mitigate these air-related impacts are discussed.

5. Descriptions of the Coal-Dominated Scenarios

As discussed in chapter 3 and in the introduction to this part of the report, the five scenarios chosen for the most detailed impact analysis call for the continued use of coal for electrical generation in the ORBES region through the year 2000. However, a variety of policy assumptions differentiate these coal-dominated futures from each other.

As shown in figure 5-1, the base case is the scenario to which all others are compared. Although the base case is relatively conventional in terms of its assumptions about the ORBES region--following historical trends--there are two major exceptions. The first exception is that the assumed rate of regional electricity demand growth is historic only through 1985. From 1985 through 2000 a lower rate is assumed. The second major exception is that full compliance with air and land environmental regulations is assumed; to date, however, such compliance has not been achieved.

Figure 5-1 also shows the basic variations between the base case and the other coal-dominated scenarios. The second coal-dominated future, the strict environmental control case, differs from the base case only with regard to the stricter environmental regulations assumed. On the other hand, air quality regulations are less stringent than those of the base case in the scenario in which noncompliance with state implementation plans is assumed. A high rate of growth in the demand for electricity is another variation of base case conditions. In the final coal-dominated future, the electrical exports case, it is assumed that an additional 20,000 megawatts electric over that of the base case will be installed in the ORBES region. The electricity generated would be transmitted to the northeastern United States to replace oil-fired generation in that part of the country.

SOCIAL VALUES. Two major sets of social values are implicit in the assumptions made concerning the coal-dominated futures. These are (1) economic benefit, material comfort, and progress/growth, which come from policies that promote a high economic growth rate, and (2) government activity and nationalism, especially in regard to fuel policy, since implementation of these scenarios would decrease U.S. dependence on foreign oil. In addition, an increased emphasis on health and safety is implicit in the strict environmental control case.[1]

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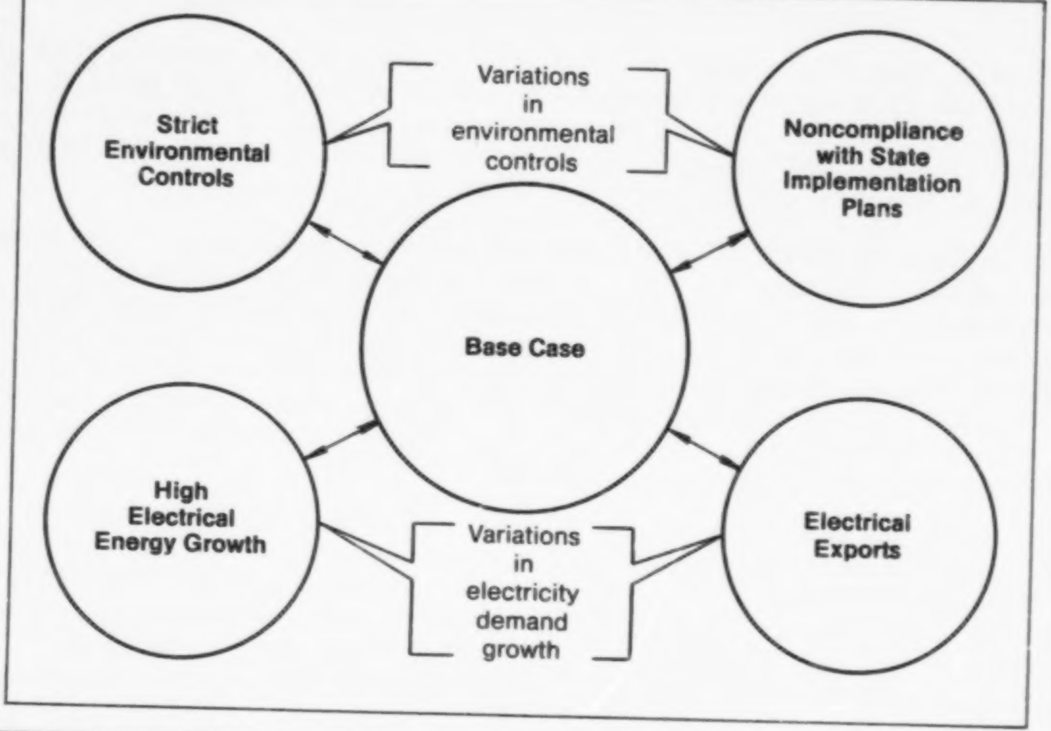
[1] See Harry R. Potter and Heather Norville, Ohio River Basin Energy Study: Social Values and Energy Policy (ORBES Phase II).

Figure 5-1
Major Variables and Comparisons
Base Case and Other Coal-Dominated Scenarios


Strict Environmental Controls
Variations in environmental controls
Noncompliance with State Implementation Plans
Base Case
High Electrical Energy Growth
Variations in electricity demand growth
Electrical Exports

POPULATION AND ECONOMIC GROWTH. The same annual regional population growth is assumed for all ORBES scenarios. Between 1970 and 2000, population would grow by 15 percent, resulting in a regional population of 26.6 million persons in the year 2000, or 3.5 million more than in 1970. The same fertility rate also is assumed for all scenarios: 2.1 lifetime births per woman (that is, the population replacement rate). Also common to all the scenarios is the assumed regional economic growth rate: an annual average rate of 2.47 percent between 1974 and 2000.[2]

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[2] See Walter P. Page, Doug Gilmore, and Geoffrey Hewings, *An Energy and Fuel Demand Model for the Ohio River Basin Energy Study Region* (ORBES Phase II).

ENVIRONMENTAL STANDARDS. Among the coal-dominated scenarios, environmental standards are assumed to be the same for the base case, the high electrical energy growth case, and the electrical exports case. Most of these assumed standards are defined in terms of what currently exists as applied to present and future sources of pollution. For air, controls are defined as the application of existing standards (as of September 1978) contained in the state implementation plans (SIPs) developed for specific states under the Clean Air Act. New source performance standards (NSPS) or revised new source performance standards (termed RNSPS in this report) are applied to all new sources of pollution, according to when they are scheduled.[3] The controls for land reclamation are derived from federal standards prior to the 1977 Surface Mining Control and Reclamation Act.[4] For water, the standards consist of current practices for the design and construction of industrial, municipal, and electrical generating facilities. Wasteload management practices, however, reflect treatment and recycling practices of older sources rather than the practices performed by new sources.[5] With regard to environmental protection of air and land quality, then, the base case, the high electrical energy growth case, and the electrical exports case reflect the full implementation of current policies.

The strict environmental control case calls for more stringent environmental regulations. In the case of air, strict controls mean that the generally stringent pollutant emission standards for urban areas set by current (as of September 1978) state implementation plans would be applied throughout a state. For water, guidelines were developed under strict controls that would reduce power plant effluents by about 95 percent from base case conditions. It also was assumed that strict environmental controls would result in a two-fold drop in stream pollutant background levels by the year 2000; in reality, however, such a decrease is unlikely. Strict environmental controls on land reclamation call for interim and permanent performance standards under the Surface Mining Control and Reclamation Act of 1977, but with strengthening of site-specific applications; state standards may exceed federal ones. Special interim and permanent standards are applied to steep-slope mining, mountaintop removal, the mining of prime farmland, and the surface effects of underground mining.

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[3] See James J. Stukel, ed., Ohio River Basin Energy Study: Air Quality and Related Impacts (ORBES Phase II) (3 vols.), for descriptions of air quality paramaters under all the scenarios.

[4] See J.C. Randolph and W.W. Jones, Ohio River Basin Energy Study: Land Use and Terrestrial Ecology (ORBES Phase II), for land reclamation assumptions under the various scenarios.

[5] See Clara Leuthart and Hugh T. Spencer, Fish Resources and Aquatic Habitat Impact Assessment for the Ohio River Basin Energy Study Area (ORBES Phase II), for the water-related assumptions made under the scenarios.

In the SIP noncompliance case, environmental regulations for land and water are the same as in the base case. With regard to air, however, it is assumed that present state implementaion plans will not be enforced. Currently SIPs for sulfur dioxide and particulates exist in all six of the ORBES states. A SIP for oxides of nitrogen exists only in the urban areas of Illinois.

ENERGY AND FUEL USE. The coal-dominated futures are further defined by a variety of energy and fuel use characteristics; growth rates for the various sectors under each scenario appear in table 5-1.[6] The push to coal produces large percentage increases in the use of regional coal between 1974 and 2000, decreases in the use of natural gas, and modest increases in the use of refined petroleum products. Electricity growth ranges from an annual average rate of 3.13 in the the base case, the strict environmental control case, and the SIP noncompliance case; to 3.20 percent in the electrical exports case; to 3.90 percent in the high electrical energy growth case. The high rate of electricity demand growth under the latter scenario is that suggested in recent estimates made by the National Electric Reliability Council (NERC).[7]

The varying assumptions about electricity demand growth lead to an installed regional electrical generating capacity of 153,245 megawatts electric in the year 2000 under the base case, the strict environmental control case, and the SIP noncompliance case; 173,395 megawatts under the electrical exports case; and 178,372 megawatts under the high electrical energy growth case. Coal-fired generating units are assumed to have 35-year lifetimes under all scenarios except the high electrical energy growth case, in which 45-year lifetimes are assumed.

COAL SUPPLY. In all ORBES scenarios, it is assumed that the coal to supply regional generating units comes from Bureau of Mines (BOM) districts in the six ORBES states (districts 1 through 4 and 6 through 11). In the high-sulfur category (coal of 1.8 percent sulfur or more), the largest percentage increase in coal production between 1974 and 2000 would occur in BOM districts 1 and 3. The percentage of high-sulfur coal, both surface and underground, would remain

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[6] For discussion, see Page, Gilmore, and Hewings, *An Energy and Fuel Demand Model*.

[7] See *Summary of Peak Load, Generating Capability, and Fossil Fuel Requirements, 1979* (National Electric Reliability Council, July 1979).

Table 5-1
Growth Rates and Installed Capacity, ORBES Region, Coal-Dominated Scenarios (1974–2000), Annual Averages

Scenario	Economic Growth	Electricity Growth	Coal Growth	Natural Gas Growth	Refined Petroleum Growth	Energy Growth	Installed Capacity Year 2000 (MWe)
Base Case	2.47%	3.13%	2.40%	−0.40%	0.37%	1.49%	153,245
Strict Environmental Controls	2.47%	3.13%	2.47%	−0.40%	0.37%	1.53%	153,245
Noncompliance with State Implementation Plans	2.47%	3.13%	2.40%	−0.40%	0.37%	1.53%	153,245
High Electrical Energy Growth	2.47%	3.90%	N/A	−0.40%	0.37%	N/A	178,372
Exports of Electricity	2.47%	3.20%	2.77%	−0.39%	0.43%	1.73%	173,395

the same among scenarios, although there would be differences among coal districts. As in the base year, districts 7 and 8 would provide no high-sulfur coal in the year 2000. In the low-sulfur category (coal of less than 1.8 percent sulfur), the largest percentage increase in production between 1974 and 2000 is assumed to occur in BOM districts 1 and 3; output in districts 7 and 8 is estimated to increase by a somewhat smaller percentage. Among the ORBES scenarios, the absolute coal tonnages arising from the various groups of districts would vary, but the percentage differences produced by these groups of districts would be the same across scenarios.[8]

SITING. In all ORBES scenarios, it is assumed that sited generating unit additions in the region announced by utility companies as of December 31, 1976, including both coal-fired and nuclear-fueled facilities, will be built as planned. The announced fuel type, unit size, and location are assumed to

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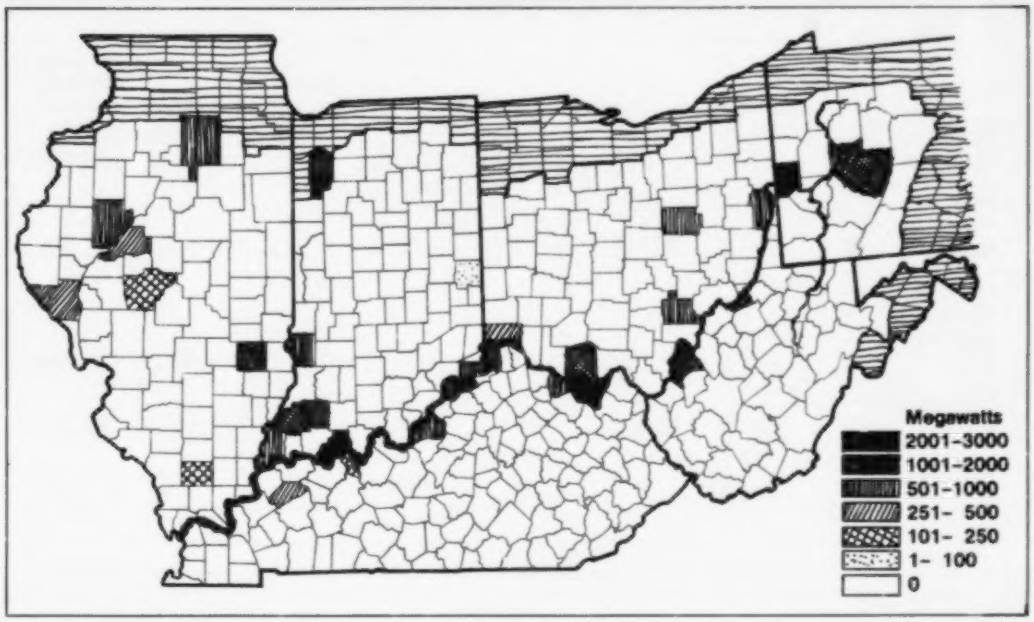
[8] See Walter P. Page, An Economic Analysis of Coal Supply in the Ohio River Basin Energy Study Region (ORBES Phase II), and Donald A. Blome, Coal Mine Siting for the Ohio River Basin Energy Study (ORBES Phase II).

Figure 5-2
Announced Coal-Fired Electrical Generating Capacity Additions, ORBES Region, 1976–85



be identical to utility plans.[9] The dates on which these facilities will come on-line are assumed to be the same as those announced by the utilities.[10]

Between 1976 and 1985, the utilities have scheduled 68 coal-fired and 13 nuclear-fueled electrical generating units of varying size in the ORBES region. These 81 units total 43,799 megawatts electric. Most of this capacity will be built along the main stem of the Ohio River (about 25,500 megawatts) and its tributaries (about 10,500 megawatts). Among the ORBES

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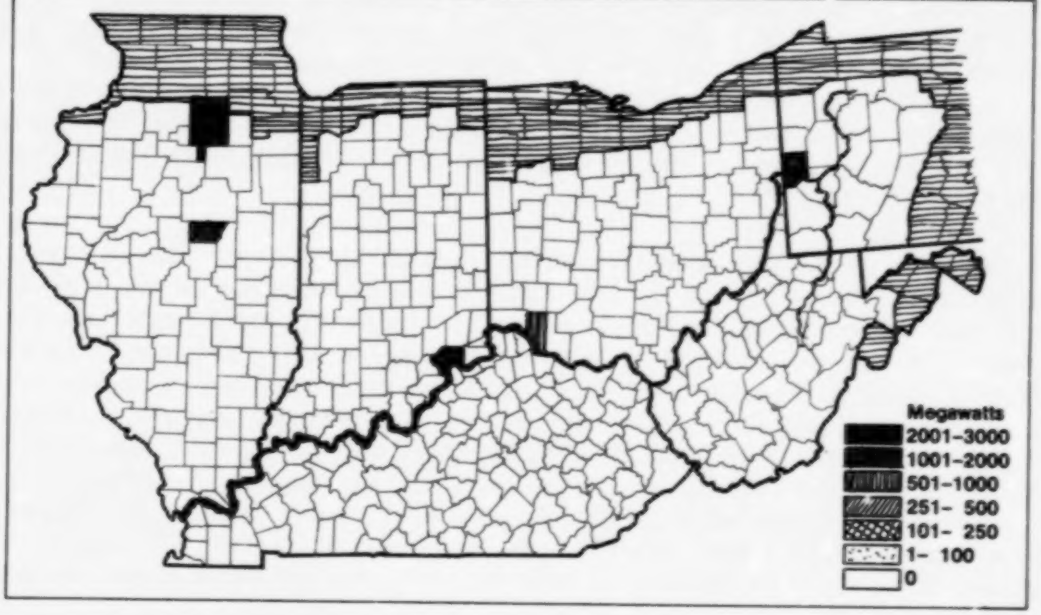
[9] For an inventory of existing and planned electrical generating units in the six ORBES states, see Steven D. Jansen, Electrical Generating Unit Inventory, 1976-1986: Illinois, Indiana, Kentucky, Ohio, Pennsylvania, and West Virginia (ORBES Phase II).

[10] Exceptions were made in the case of two scenarios (see chapter 13). See Gary L. Fowler et al., The Ohio River Basin Energy Facility Siting Model: Methodology (vol. I) (ORBES Phase II), for a full description of the siting methodology.

Figure 5-3
Announced Nuclear-Fueled Electrical Generating Capacity Additions
ORBES Region, 1976–85



state portions, most of the capacity additions are scheduled in Indiana, where over 11,000 megawatts electric are planned, 80 percent coal fired and 20 percent nuclear fueled. Illinois follows, with about 8500 megawatts electric, 52 percent coal fired and 48 percent nuclear fueled. All of the nearly 9000 megawatts electric scheduled for Kentucky are coal fired. The remaining capacity additions are accounted for in Pennsylvania (nearly 8000 megawatts electric, 77 percent coal fired and 23 percent nuclear fueled), Ohio (less than 5000 megawatts electric, 83 percent coal-fired and 17 percent nuclear fueled), and West Virginia (slightly over 2500 megawatts electric, all of it coal fired). Although additions scheduled from 1986 through the year 2000 are less certain, nonetheless they also are assumed to come on-line as planned by the utilities. The utility-announced coal-fired capacity additions scheduled between 1975 and 1985 are depicted in figure 5-2; the utility-announced nuclear-fueled capacity additions, in figure 5-3.

In order to fill the increment between electricity to be supplied by planned coal-fired and nuclear-fueled facilities and the demand for electricity projected under each scenario, standard 650 megawatt electric coal-fired generating units are sited in the region after 1985. No additional nuclear-fueled generating units are sited to meet the scenario demands beyond those already planned by the utilities. The siting patterns of the various scenarios differ according to the policy assumptions made for each scenario.[11]

Under the base case, 95 standard coal-fired units are sited in the study region after 1985. These 95 incremental units are concentrated in counties bordering the Ohio River main stem and its tributaries, particularly in the upper Ohio River Basin along the main stem, in the coalfields of southeastern Ohio, and in counties bordering the Monongahela and Allegheny rivers in Pennsylvania. (The SIP noncompliance pattern is the same as that of the base case.) Figure 5-4 depicts the coal-fired generating capacity in the year 2000 under the base case.[12]

Although the installed capacity under the base case, the SIP noncompliance case, and the strict control case is the same in the year 2000, the strict environmental control assumptions lead to a more dispersed siting pattern for post-1985 electrical generating unit additions. Capacity additions along the middle and lower Ohio River main stem are concentrated on the reach from Cincinnati, Ohio, to Louisville, Kentucky, and in southwestern Indiana and southeastern Illinois in counties bordering the Wabash River. However, strict air quality standards restrict the number of suitable sites along the Ohio River main stem. Consequently, more units are located on smaller tributaries away from the main stem, in areas of lower water availability. Fifteen reservoirs are required to accommodate the dispersed siting pattern.[13]

The installed capacity is higher under the two remaining coal-dominated scenarios, the high electrical energy growth case and the electrical exports case. Under the high electrical energy growth scenario, additional units over those of the base case are sited off the Ohio River main stem, on its major tributaries. Under the electrical exports case, 20,000 megawatts electric over the base case are sited to replace oil-fired capacity on the East Coast with coal-fired capacity in the ORBES region. Because of the distances involved in "transporting" the electricity to the East, the additional units are sited in the eastern portion of the ORBES region and in close proximity to

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[11] See Gary L. Fowler et al., The Ohio River Basin Energy Facility Siting Model: Sites and On-Line Dates (vol. II) (ORBES Phase II).

[12] The siting patterns of all the coal-dominated scenarios appear in Fowler et al., The Ohio River Basin Energy Facility Siting Model (vol. II).

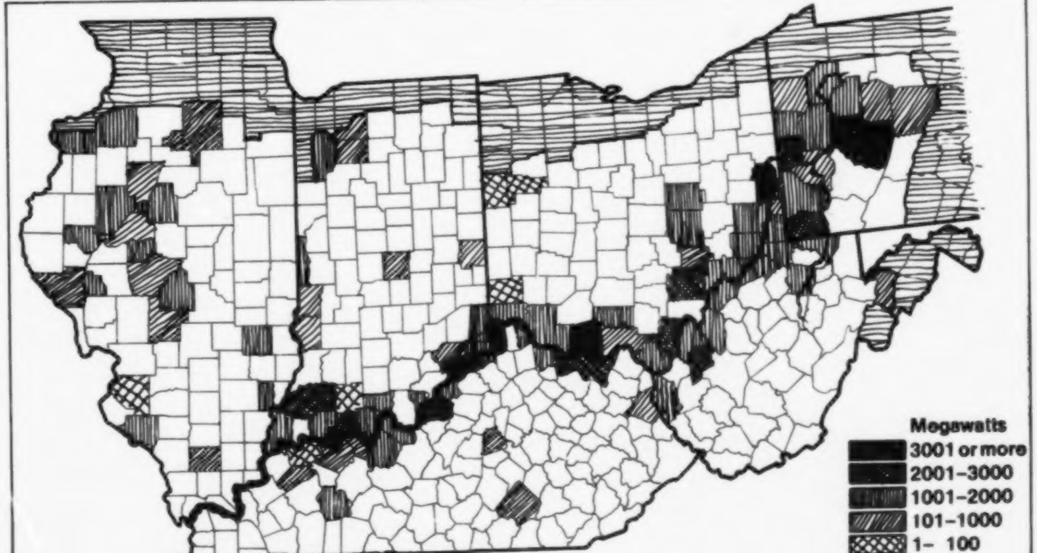
[13] For details, see E. Downey Brill, Jr., et al., Potential Water Quantity and Water Quality Impacts of Power Development Scenarios on Major Rivers in the Ohio Basin (ORBES Phase II).

Table 5-2
Coal-Fired Capacity Additions, ORBES Region, Coal-Dominated Scenarios, 1986–2000

ORBES State Portion	Number of Scenario Unit Additions: Base Case and SIP Noncompliance	Strict Environmental Controls	High Electrical Energy Growth	Exports of Electricity
Illinois	13	13	18	13
Indiana	18	18	25	18
Kentucky	16	16	28	18
Ohio	20	20	32	33
Pennsylvania	14	14	16	19
West Virginia	14	14	25	25
Total Units	95	95	144	126

Note: Standard coal-fired capacity additions are 650 megawatts electric per unit. Included in the figures are units scheduled by the utilities through 2000; these units are of varying megawattage.

Figure 5-4
Coal-Fired Electrical Generating Capacity, ORBES Region, Base Case, Year 2000



major coalfields. Those units dedicated to exports are added to existing utility sites (either announced or designated in the base case). Each county with scenario unit additions is limited to a total megawattage of 2600.

Table 5-2 presents the number of scenario unit additions for each of the coal-dominated scenarios.

6. Comparison of Impacts among Coal-Dominated Scenarios

In general, the different assumptions of the five ORBES coal-dominated scenarios affect the level of utility air emissions more than they affect any other impact area examined. The magnitude and distribution of these emissions consistently correlate with ambient air concentrations and, thus, with crop losses and emission-related mortality. Therefore, in section 6.1, the air-related impacts of the coal-dominated scenarios are examined. In section 6.2, some of the costs associated with the air-related impacts are discussed: (1) cumulative capital costs for installing new generating capacity and pollution control devices, (2) electricity prices, and (3) agricultural dollar losses. Finally, in section 6.3, other environmental and social impacts that the expanded generating capacity could entail are noted. In general, the impacts of expanded regional generating capacity on regional land use, terrestrial ecology, employment, and non-emission-related injuries and mortality are about the same under the base case, the strict environmental control case, and the SIP noncompliance case. The high electrical energy growth case and the electrical exports case would result in greater impacts in these latter areas than the first three coal-dominated scenarios. Regional water quality would be affected similarly by the projected generating capacity, regardless of the scenario.

6.1 Emissions, Concentrations, and Air-Quality-Related Impacts

SULFUR DIOXIDE

SIP Compliance. Under all the coal-dominated scenarios, total utility sulfur dioxide emissions would decrease by the year 2000 from their 1976 levels (see table 6-1).[1] However, the rate of decrease and the actual totals in 2000 would vary among the scenarios (see figure 6-1). The scenario assumptions that produce the differences charted in table 6-1 and figure 6-1 lead to several observations about possible strategies to reduce sulfur dioxide emissions at the individual plant level from their high 1976 levels. A fuller discussion of mitigation strategies--both at the individual plant level and in an organizational context--appears in chapter 12.

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[1] For a discussion of air pollutant emissions and the resulting concentrations, see James J. Stukel and Brand L. Niemann, Documentation in Support of Key ORBES Air Quality Findings; Teknekron Research, Inc., Air

Figure 6-1
Electric Utility Sulfur Dioxide Emissions in the ORBES Region, Coal-Dominated Scenarios

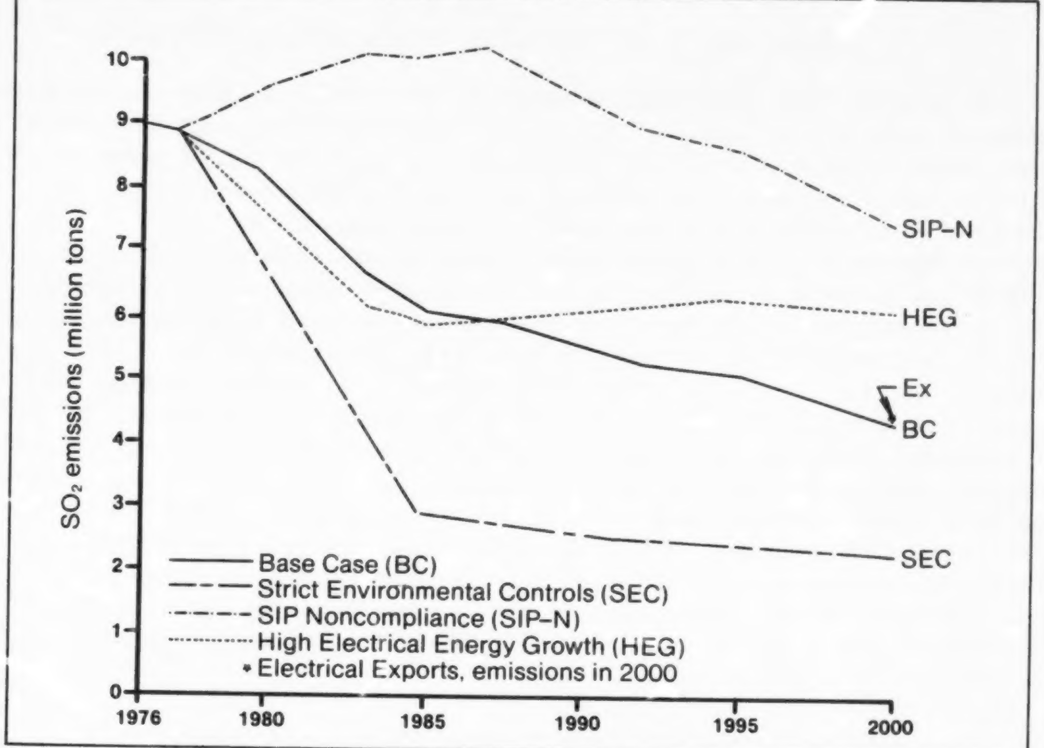


Table 6-1
Electric Utility Sulfur Dioxide Emissions in the ORBES Region, Coal-Dominated Scenarios

	BC		SEC		SIP–N		HEG		EX
	SIP	Total	SIP	Total	SIP	Total	SIP	Total	Total
	(million tons)								
1976		8.94		8.94		8.94		8.94	8.94
1980	7.95	8.14	6.89	7.08	9.50	9.62	7.65	7.84	—
1985	5.60	6.10	2.49	2.99	9.88	10.10	5.45	5.93	—
1990	4.73	5.55	1.94	2.74	9.00	9.45	5.20	6.07	—
1995	3.98	5.16	1.55	2.73	7.85	8.66	4.91	6.24	—
2000	2.93	4.35	1.15	2.55	6.47	7.55	4.32	6.06	4.55

First, the base case, the high electrical energy growth case, and the SIP noncompliance case demonstrate how sensitive regional sulfur dioxide emissions are to compliance with and enforcement of state implementation plans (SIPs). Under both the base case and the high growth case it is assumed that complete SIP compliance will occur by 1985.[2] As a result, under both scenarios, total utility sulfur dioxide emissions would be reduced continuously and dramatically between 1976 and 1985, and at about the same rate. The SIP noncompliance scenario, however, assumes that there will be no utility compliance schedule; SIP units would continue burning historic coals and using emission controls as in 1976. Thus, under this latter case, annual utility sulfur dioxide emissions would increase between 1976 and 1985, ensuring that the air quality problems of the base period would continue and perhaps get worse. Since nearly the same annual electrical generation is assumed in all of these scenarios through 1985, the immediate benefits of SIP compliance are clear: total utility sulfur dioxide emissions could be reduced by one-third by 1985 from their 1976 levels.

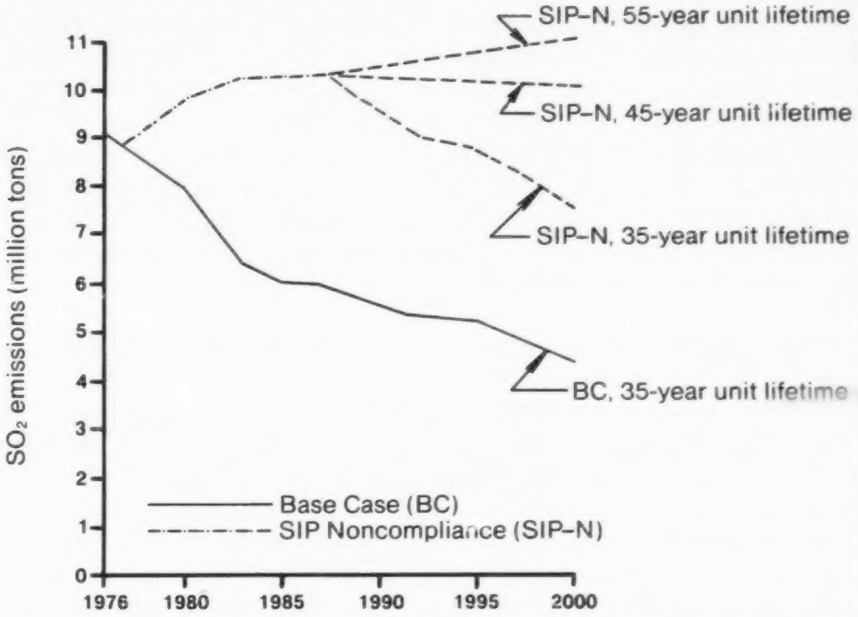
Plant Retirements. Utility sulfur dioxide emission patterns between 1985 and 2000 suggest yet another way to control emissions of this pollutant. After 1985, utility sulfur dioxide emissions under the same three scenarios would parallel the retirement of SIP units, which would be replaced by units governed by new source performance standards (NSPS) and revised new source performance standards (RNSPS). Under both the base case and the noncompliance case, it is assumed that SIP units will be retired after 35 years; under the high growth case, generating units would have 45-year lifetimes.[3] As figure 6-1 indicates, sulfur dioxide emissions thus would decrease between 1985 and 2000 under the first two scenarios and would increase slightly under the last scenario.

Quality and Meteorology in the Ohio River Basin: Baseline and Future Impacts; and Teknekron Research, Inc., Selected Impacts of Electric Utility Operations in the Ohio River Basin (1976-2000): An Application of the Utility Simulation Model (vols. I, II, and III, respectively, of James J. Stukel, ed., Ohio River Basin Energy Study: Air Quality and Related Impacts (ORBES Phase II)).

[2] Most plants are assumed to comply with SIPs by switching to coals lower in sulfur than those presently used or by switching to cleaned coals. Thus, less than half the existing capacity would be retrofitted with flue gas desulfurization devices ("scrubbers") under the base case. The costs of retrofitting are discussed in section 6.2.

[3] A 35-year life for coal-fired units would lead to the retirement of about one-third of existing SIP capacity by the year 2000. A 45-year life would lead to the retirement of only about 8 percent of existing SIP capacity by that year.

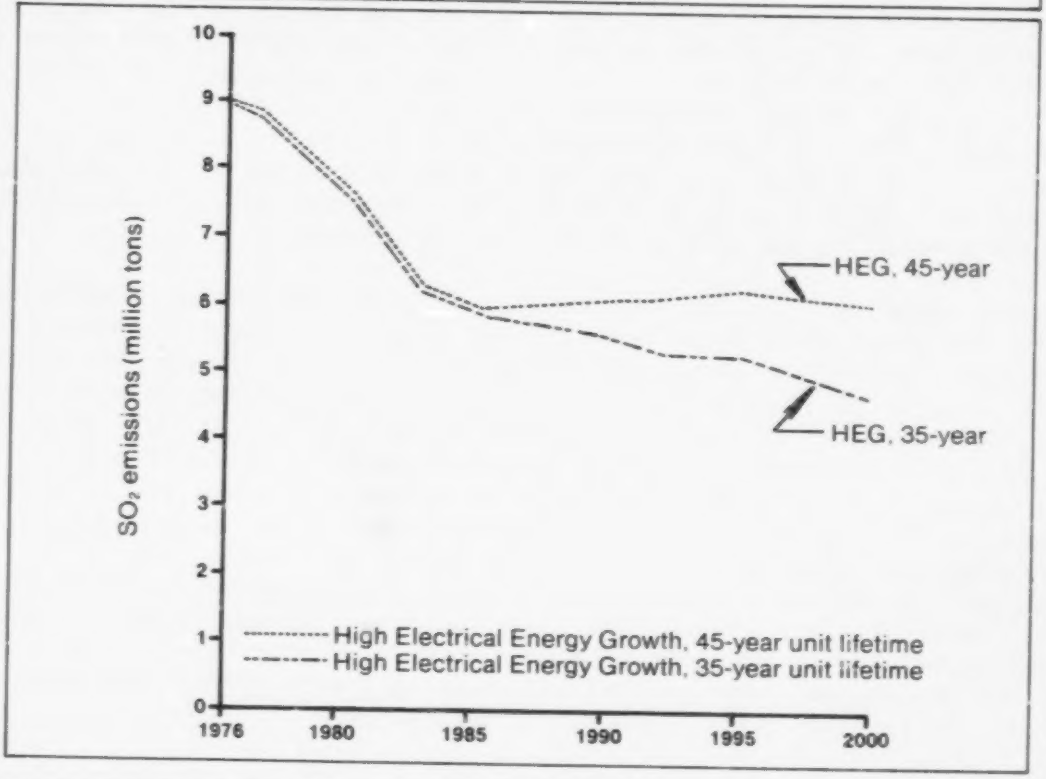
Figure 6-2
Electric Utility Sulfur Dioxide Emissions in the ORBES Region, Base Case and SIP Noncompliance Case



However, given the costs of installing new generating capacity and the costs of complying with the stricter NSPS and RNSPS controls, it is quite possible that utilities may postpone the retirements of SIP units. Under two scenarios--noncompliance and high growth--this possibility was examined briefly. Figure 6-2 indicates the utility sulfur dioxide emission rates that would occur under noncompliance if 35-, 45-, or 55-year generating unit lifetimes are assumed. Figure 6-3 compares the high growth case that assumes a 45-year lifetime with a variation that is identical except for a 35-year lifetime assumption. Both of these figures demonstrate the difference that early retirement of SIP units could have on regional utility sulfur dioxide emission levels. A 45-year SIP unit lifetime under SIP noncompliance, for example, could increase emission levels about 34 percent in the year 2000 over the already high levels that would be recorded under the SIP noncompliance case with 35-year lifetimes.

Another consideration in regard to the retirement of SIP units concerns modifications to such units. That is, since the periodic maintenance of a SIP

Figure 6-3
Electric Utility Sulfur Dioxide Emissions in the ORBES Region, High Electrical Energy Growth Case



plant can result in a substantial renovation of that plant, it may not be retired as early as it would have been otherwise. If, however, certain modifications were considered major enough to warrant the reclassification of SIP units from an existing to a new source category, such a revised definition might result in a utility's evaluation of the relative merits of (1) continuing to use an existing unit or (2) building a new one. If existing SIP units were retired because of such an evaluation, substantial emission reductions could result.

The 35-year retirement of SIP units still would not wholly alleviate the air quality problems stemming from regional sulfur dioxide emissions. Even in 2000, SIP-regulated units would account for the bulk (at least 67 percent) of total regional utility sulfur dioxide emissions, regardless of whether a 35- or a 45-year lifetime is assumed (see table 6-1). However, SIP units would account for between 15 and 40 percent of the regional electrical generation in the year 2000 depending on the scenario. For example, SIP units would emit 2.93 million tons of sulfur dioxide in the year 2000 under the base case (or 67 percent of all utility sulfur dioxide emissions) and would produce about 24 percent of the total regional generation. Under the SIP noncompliance case, SIP units would emit 6.47 million tons in 2000 (86 percent of the total) and would account for about 40 percent of the total regional generation of electricity. These examples thus suggest that the emission contribution of SIP units would be disproportionate to the benefits of SIP generation in the year 2000. SIP units contribute such a major portion of the total utility sulfur dioxide emissions in 2000 and a lower percentage of the generation because each SIP unit emits about five to six times more sulfur dioxide than a new plant supplying the equivalent amount of electricity.

Stricter Controls. One way to achieve a more balanced emission-generation ratio would be to tighten the SIP compliance strategies currently in existence. The strict environmental control case offers an example of what might be expected if such stricter controls were enacted and enforced. This latter case assumes that in each ORBES state the state's urban SIPs--which are stricter than rural SIPs--would be applied throughout the ORBES portion of that state.[4] As a result of such strict controls, utility sulfur dioxide emissions would decrease more by the year 2000 under this scenario than under any other coal-dominated scenario (see figure 6-1 and table 6-1). In addition, the rate of decrease would be more rapid under the strict control case. Moreover, in the year 2000 under the strict control case, SIP units would emit 1.15 million tons of sulfur dioxide (or 45 percent of the total regional utility emissions of this pollutant) and would account for about 24 percent of the total regional electrical generation.

Least Emissions Dispatching. Another way to achieve a more balanced emission-generation ratio would be to use least emissions dispatching. At present, and under all of the coal-dominated scenarios, generating units are loaded (brought on-line) in order of operating costs. As a result, SIP units are the first units dispatched, since newer units are more expensive to operate.

Under the high growth case, a variation was examined that assumed that coal-fired units would be dispatched according to least emissions of sulfur dioxide. Under the least emissions criterion, the units emitting the most sulfur dioxide (on a per Btu basis) would be loaded last. Under one such dispatching order, for example, RNSPS units might be dispatched first, then

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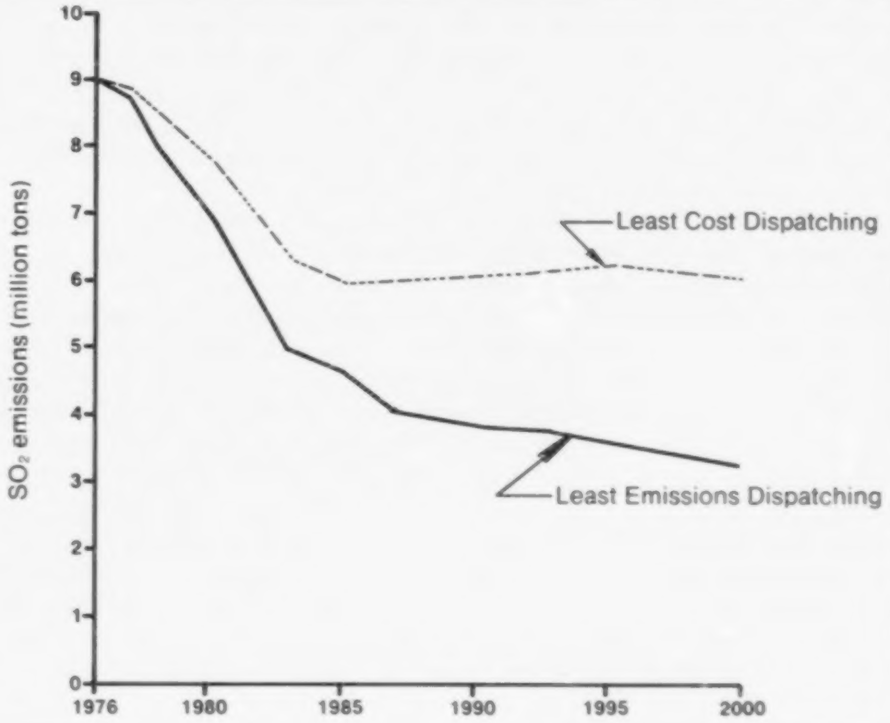
[4] Because of this assumption of stricter controls, almost all of existing SIP capacity would need to be retrofitted with flue gas desulfurization devices, compared with about one-third of existing capacity under the base case.

NSPS units, then urban SIP units, and finally rural SIP units.[5] While such a dispatching order may not always be possible, the results of such dispatching under the high growth variation indicate that it is an alternative worth consideration. Total regional utility sulfur dioxide emissions would be 55 percent lower under this least emissions policy than they would be under the least cost policy in the year 2000 (see figure 6-4). SIP emissions alone

Figure 6-4
Electric Utility Sulfur Dioxide Emissions in the ORBES Region, Dispatching Variations under High Electrical Energy Growth



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[5] It is interesting to note that such a dispatching policy would reduce the proportion of generation that actually would occur in the ORBES region. Such a reduction would occur because the region has a high proportion of high-emission SIP capacity compared to the proportion in the utility service areas that are partially outside the region. Thus, if least emissions dispatching were to be implemented, some generation probably would be shifted to the plants outside the ORBES region.

would be 35 percent lower under the former case than under the latter case. Moreover, in the year 2000 under the least emissions dispatching variation, SIP units would emit 1.5 million tons of sulfur dioxide--or 45 percent of all utility sulfur dioxide emissions--and account for about 15 percent of the electrical generation projected under this scenario. Under the least cost policy, on the other hand, SIP units would emit 4.32 million tons of sulfur dioxide--or 71 percent of the total utility emissions--and account for about 25 percent of the total electrical generation projected under this scenario.

As this discussion of utility sulfur dioxide emissions under the different coal-dominated scenarios has revealed, the current emission standards, if complied with, would reduce total sulfur dioxide emissions between 1976 and 1985 from the 1976 levels. Any further reductions would be determined by the lifetimes of SIP plants. As discussed below, such further reductions would be important since episodic concentrations still would result from the 1985 emission levels of most of the scenarios. Before such concentrations are discussed, however, utility particulate and nitrogen oxide emission trends under the coal-dominated scenarios are examined.

PARTICULATE EMISSIONS. Utility particulate emissions would be reduced significantly by the year 2000 from the 1976 levels under all of the coal-dominated scenarios except the SIP noncompliance case (see table 6-2). Moreover, except under the latter scenario, utility particulate emissions would be reduced at about the same rate and would be about the same in 2000--nearly five times lower than the 1976 emissions (see figure 6-5). In addition, the least emissions dispatching variation would result in utility particulate emission levels about the same as those charted in figure 6-5. SIP noncompliance, however, would result in increased utility particulate emissions through 1985. As a result, in 2000 under SIP noncompliance, utility particulate emission levels would be only slightly lower than the 1976 levels. These scenarios thus suggest that current particulate standards--which are the same in urban and rural settings--will be effective as applied to the utility industry. One major reason for this effectiveness is that particulate removal technology is assumed to be between 85 and 94 percent efficient depending on when the unit was built.

NITROGEN OXIDE EMISSIONS. All scenarios would result in increased utility emissions of oxides of nitrogen (see table 6-3). Similarly, except under the high electrical energy growth scenario, utility nitrogen oxide emissions would increase at about the same rate through 1985 and would be nearly the same in 2000--approximately 35 percent higher than the 1976 emissions (see figure 6-6).[6] There are two reasons for this similarity among the scenarios. First,

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[6] Throughout this report, the term nitrogen oxide emissions refers to emissions of oxides of nitrogen, not emissions of nitrogen oxide alone.

Figure 6-5 Electric Utility Particulate Emissions in the ORBES Region, Coal-Dominated Scenarios

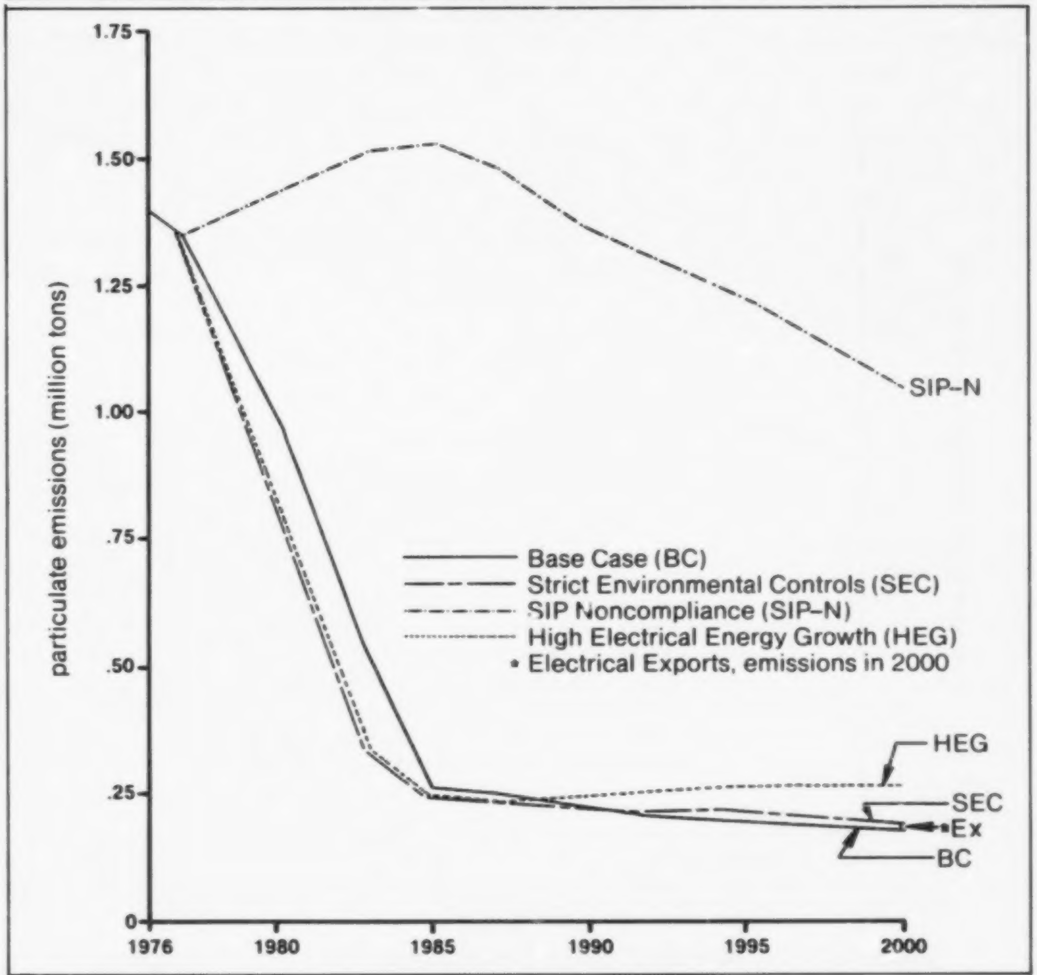

Table 6-2 Electric Utility Particulate Emissions in the ORBES Region, Coal-Dominated Scenarios

	BC	SEC	SIP–N	HEG	EX
			(million tons)		
1976	1.38	1.38	1.38	1.38	1.38
1980	0.83	0.83	1.44	0.83	—
1985	0.25	0.25	1.53	0.25	—
1990	0.22	0.24	1.37	0.25	—
1995	0.21	0.23	1.23	0.26	—
2000	0.19	0.21	1.06	0.26	0.20

Figure 6-6
Electric Utility Nitrogen Oxide Emissions in the ORBES Region, Coal-Dominated Scenarios

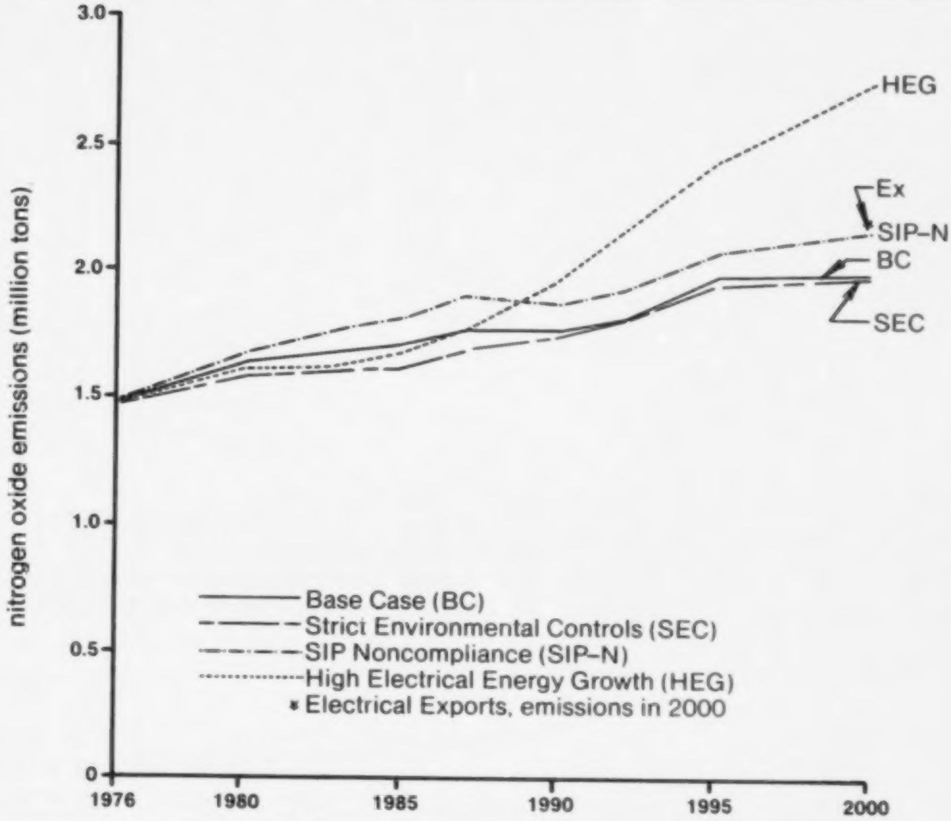

Table 6-3
Electric Utility Nitrogen Oxide Emissions in the ORBES Region, Coal-Dominated Scenarios

	BC	SEC	SIP–N	HEG	EX
			(million tons)		
1976	1.49	1.49	1.49	1.49	1.49
1980	1.63	1.60	1.66	1.63	—
1985	1.71	1.69	1.82	1.67	—
1990	1.77	1.74	1.88	1.93	—
1995	1.98	1.96	2.08	2.34	—
2000	2.00	1.99	2.16	2.63	2.22

nitrogen oxide emission limits do not exist for SIP plants in the ORBES region, except in the urban areas of Illinois. Second, the same nitrogen oxide emission limits were assumed for new units under all scenarios. Thus, utility nitrogen oxide emissions would increase from the 1976 levels primarily in proportion to electricity demand growth and to the lifetime of SIP units. This last point also explains why, after 1985, utility nitrogen oxide emissions would increase at a faster rate under the high growth case than under the other scenarios: the high growth case has the highest electricity demand growth and assumes 45-year SIP unit lifetimes instead of the 35-year lifetimes assumed under the other coal-dominated scenarios. Specifically, utility nitrogen oxide emissions in 2000 under high growth would be 18 percent higher than the next highest emissions--those under the electrical exports case--and 77 percent higher than the 1976 emissions.

POLLUTANT CONCENTRATIONS. The magnitude of utility sulfur dioxide emission levels under each scenario corresponds to annual average (long-term) and episodic (short-term) sulfur dioxide and sulfate concentrations. Moreover, since the transformation of sulfur dioxide into sulfates contributes to concentrations of total suspended particulates (TSP) (see section 4.3), reductions in both utility particulate emissions and utility sulfur dioxide emissions could reduce TSP concentrations. However, the ratio of the lower ORBES region's contribution to sulfur dioxide and sulfate concentrations in the upper region is not likely to change from the ratio during the base period (see section 4.3) under any of the scenarios.

Many of the same statements made about the emissions under the coal-dominated scenarios also apply to annual concentrations under these scenarios. For example, regardless of scenario, the regional annual average sulfur dioxide and sulfate concentrations in 2000 attributable to utility emissions would be lower than the present concentrations (see table 6-4).[7] Again, it is the strict environmental control case that would reduce the annual average concentrations the most and that would reduce them more rapidly than any of the other scenarios. Similarly, the high electrical energy growth case and the SIP noncompliance case would result in the least reduction by the year 2000. In fact, concentrations even would increase through 1985 under the noncompliance case. In general, most concentration reductions would occur by 1985--regardless of scenario--provided that SIP plants have complied by that

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[7] The percentages listed in both table 6-4 and table 6-5 are the changes in the area of highest concentration. An "area" is based on the averaging method of a grid pattern of 80-by-80 kilometers. Thus, while such an average represents the highest concentration area, specific locations within or outside of the 80-by-80 kilometer area may experience higher or lower concentrations.

Table 6-4
Sulfur Dioxide and Sulfate Annual Average Concentrations, ORBES Region, Percent Change from 1976, Highest Concentration Region

Pollutant	Concentration, 1976 ($\mu g/m^3$)	Year	Base Case	Strict Environmental Controls	SIP Noncompliance	High Electrical Energy Growth
			(%)			
Sulfur dioxide	25.88	1985	-28	-62	+16	-30
Sulfur dioxide	25.88	2000	-50	-71	-18	-29
Sulfates	9.2	1985	-27	-56	+13	-25
Sulfates	9.2	2000	-49	-66	-20	-25

date. Also, the noncompliance case and the high electrical energy growth case would result in substantially higher concentrations in 2000 than would the base case.

Another benefit of lower utility sulfur dioxide emissions is the probable reduction of the concentrations that would occur under episodic conditions. If the characteristics of the August 27, 1974, sulfate episode were to be repeated in 2000 under any of the scenarios, the predicted utility-related, short-term sulfur dioxide and sulfate concentrations would be reduced from the utility-related, short-term concentrations that were registered during that episode (see table 6-5).[8] However, since these short-term concentrations were quite high under the August 27 episode, the 31 and 25 percent reductions that would occur in 1985 under the base case still would lead to relatively high concentrations of sulfur dioxide and sulfates over the ORBES region. Even the 49 and 51 percent reductions that would occur in 2000 under the base case would result in short-term sulfur dioxide levels on the order of 30 micrograms per cubic meter and in short-term sulfate levels that could be considered marginally episodic--that is, on the order of 15 micrograms per cubic meter over a large area. On the other hand, the strict environmental control case would lead to reductions of such magnitude that the short-term levels of

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[8] As discussed in section 4.3, the August 27, 1974, episode is the most frequently occurring type of meteorological episode in the ORBES region (about 10 times per year). This type of episode involves a simple flow pattern of extremely persistent winds blowing from the west to the east over the region.

Table 6-5
Sulfur Dioxide and Sulfate Episodic Concentrations, ORBES Region, Percent Change from August 27, 1974, Episode, Highest Concentration Region

Pollutant	Concentration, 1976 (μg/m)	Year	Base Case	Strict Environmental Controls	SIP Noncompliance	High Electrical Energy Growth
				(%)		
Sulfur dioxide	94.04	1985	−31	−68	+18	−34
Sulfur dioxide	94.4	2000	−49	−75	−13	−30
Sulfates	40.1	1985	−25	−76	+16	−23
Sulfates	40.1	2000	−51	−78	−30	−18

sulfur dioxide and sulfates in both 1985 and 2000 no longer would be considered episodic. As can be deduced, therefore, the SIP noncompliance and the high electrical energy growth cases, which reduce emissions the least by 2000, would result in relatively high episodic concentrations.

Annual average and episodic concentrations are important in terms of both regional crop loss impacts and regional health impacts (among other things) since the reductions in concentrations consistently correlate with less crop loss and fewer health impacts.

PHYSICAL CROP LOSSES. In terms of agricultural impacts, studies have indicated that sulfur dioxide concentrations as low as 130 micrograms per cubic meter (one-tenth of the secondary three-hour standard) in the presence of moderate ozone levels (0.06 to 0.1 parts per million) can affect vegetation.[9] Thus, three coal-dominated scenarios--the base case, the SIP noncompliance case, and the high electrical energy growth case--were examined to determine the regional acreage that could be affected by the sulfur dioxide concentrations attributable to utility emissions in the ORBES region. Of these three scenarios, the SIP noncompliance case would subject the most regional acreage to such concentrations in both 1985 and 2000. However, except for the SIP noncompliance case in 1985, all three of these coal-dominated scenarios would subject less regional acreage to such concentrations than was subjected in 1976 (approximately 12.2 million acres). Thus, while about 10 percent of the ORBES region experienced such concentrations in 1976, 3.1 percent, 4.5 percent, and 6.0 percent would experience such concentrations in 2000 under the base case, the high growth case, and the noncompliance case, respectively.

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[9] For a discussion of vegetation impacts and losses, see Orie Loucks et al., Crop and Forest Losses Due to Current and Projected Emissions from Coal-Fired Power Plants in the Ohio River Basin (ORBES Phase II).

Each of these three coal-dominated scenarios also was examined to determine the impact of such affected acreage on crop yields in the presence of moderate ozone levels. As discussed previously (see section 4.4), between 867,000 and 6.1 million bushels of three selected crops--soybeans, corn, and wheat--were estimated to have been lost in 1976 because of such utility-related sulfur dioxide concentrations; the probable loss was projected to be 3.2 million bushels. Under these three scenarios, crop yield losses would not be as high in 1985 and 2000 as they were in 1976 (see table 6-6). However, because utility sulfur dioxide emissions would be higher under the SIP noncompliance case and because more acreage would be affected by the resulting sulfur dioxide concentrations of 130 micrograms per cubic meter, noncompliance would result in the highest losses. Nevertheless, regardless of the scenario, crop losses related to sulfur dioxide concentrations in the presence of moderate ozone levels would represent less than 1 percent of the expected regional yield in any given year. However, on a local scale, such as the county, losses could be significant, and losses to individual farmers could be substantial. For example, under all three scenarios, losses in the ORBES state portions of Illinois, Indiana, and Ohio would account for approximately 95 percent of the total losses. In general, though, crop losses related to utility sulfur dioxide emissions would be only a fraction of the total losses attributable both to sulfur dioxide and to ozone formed from nitrogen oxide emissions.

As discussed in section 4.4, the majority of regional crop losses are the result of oxidants formed from nitrogen oxide emissions in combination with other pollutants. During the base period, nitrogen oxide emissions in the ORBES region originated primarily from transportation (35 percent) and from electrical generation (50 percent). However, it is projected that nitrogen oxides originating from transportation sources will decrease significantly by the year 2000. Thus, utility nitrogen oxide emissions will begin to constitute a larger proportion of the regional nitrogen oxide emissions, especially since nitrogen oxide standards do not yet exist for SIP units in the ORBES region and since emissions from these units are projected to account for the majority of all utility nitrogen oxide emissions. As a result, the rate of decrease in ozone production may be dictated by utility nitrogen oxide emissions.

As table 6.6 indicates, crop losses attributable to oxidants formed from all regional nitrogen oxide emissions would increase under each of the three scenario examined. Because both utility and nonutility nitrogen oxide

Table 6-6
Minimum, Probable, and Maximum Crop Losses Due to Regional Sulfur Dioxide and Nitrogen Oxide Emissions, ORBES Region

Year	Pollutant	Minimum	Probable	Maximum
BASE PERIOD			(thousand bushels)	
1976	Sulfur dioxide	867	3,241	6,132
1976	Ozone	117,944	258,067	480,208
	Total	118,811	261,308	486,340
BASE CASE				
1985	Sulfur dioxide	329	1,228	2,338
1985	Ozone	290,504	412,030	691,541
	Total	290,833	413,258	693,879
2000	Sulfur dioxide	248	924	1,716
2000	Ozone	99,484	171,412	358,549
	Total	99,732	172,336	360,265
SIP NONCOMPLIANCE				
1985	Sulfur dioxide	817	3,010	5,666
1985	Ozone	290,504	412,030	691,541
	Total	291,321	415,040	697,207
2000	Sulfur dioxide	564	2,189	4,078
2000	Ozone	99,484	171,412	358,549
	Total	100,048	173,601	362,627
HIGH ELECTRICAL ENERGY GROWTH				
1985	Sulfur dioxide	327	1,219	2,301
1985	Ozone	290,504	412,030	691,541
	Total	290.831	413,249	693,842
2000	Sulfur dioxide	289	1,081	2,157
2000	Ozone	369,795	468,310	705,123
	Total	370,084	469,491	707,280

Note: Crop losses related to sulfur dioxide depend on the amount of regional area affected by concentrations of 130 $\mu g/m^3$ in the presence of moderate ozone levels. The concentrations are those attributable to peak load utility SO_2 emissions (which comprise about 80% of all regional SO_2 emissions). Crop losses related to NO_x emissions are those projected to occur because of oxidants formed from all regional NO_x emissions. Finally, projected corn, soybean, and wheat losses are added to derive the numbers in this table. For the percentage that each of these crops comprises of the minimum, probable, and maximum losses, see Orie Loucks et al., *Crop and Forest Losses Due to Current and Projected Emissions from Coal-Fired Power Plants in the Ohio River Basin* (ORBES Phase II).

emissions are projected to rise similarly from 1976 to 1985 under the three scenarios examined, related crop losses would be the same in 1985--ranging from a minimum of 290 million bushels to a maximum of 691 million bushels. However, because nitrogen oxide emissions from nonutility sources are projected to decline significantly after 1985, ozone production is expected to begin leveling off after that year, even with the capacity additions projected under the base case and the SIP noncompliance case. As a result, in the year 2000 under the base case and the SIP noncompliance case, crop losses attributable to oxidants formed from nitrogen oxide emissions are projected to be lower than in 1985; they would range from a minimum of 99 million bushels to a maximum of 358 million bushels in that year. However, since the high growth case adds many more electrical generating units after 1985 than do the other two scenarios, the decrease in nonutility nitrogen oxide emissions would be offset by a larger increase in utility nitrogen oxide emissions. As a result, crop losses attributable to oxidants would range from a minimum of 369 million bushels to a maximum of 705 million bushels under the high growth case in the year 2000.

As a means of comparing the crop losses related to sulfur dioxide and ozone under the three scenarios, the cumulative probable crop losses between 1976 and 2000 were calculated for each of the three crops in question under each of the three scenarios. Each of these cumulative probable numbers then was compared to what the cumulative regional production could be if complete abatement of these pollutants (that is, "clean air") occurred. Under the base case, cumulative soybean losses would represent 26.3 percent of cumulative soybean clean air production; cumulative corn losses, 10.8 percent of cumulative corn clean air production; and cumulative wheat losses, 12.1 percent of cumulative wheat clean air production. The percentages under the SIP noncompliance case would be almost identical to those of the base case. Under the high growth case, however, cumulative soybean losses would represent 28.3 percent of the cumulative soybean clean air yield; cumulative corn losses, 15.2 percent of the cumulative corn clean air yield; and cumulative wheat losses, 12.5 percent of the cumulative wheat clean air yield.

In general, regardless of the scenario, losses due to oxidants would constitute about 99 percent of all losses expected because of sulfur dioxide and ozone (see table 6-6). The distribution of the losses due to oxidants would vary among the ORBES state portions, but the state portions of Illinois, Indiana, and Ohio again would account for about 95 percent of the losses. It should be noted that the distribution of all crop losses due to air pollution is not a local problem--that is, merely in the vicinity of a power plant--but, because of pollutant transport, these losses may occur in areas removed from major point sources.

FOREST LOSSES. The total estimated reduction in forest growth in the ORBES region in 1985 due to air pollutants, principally ozone, would be 1.3 percent to 6.3 percent of the total production regardless of the scenario. In the year 2000, losses would vary depending on energy development: under the base case and the SIP noncompliance case, projected losses are estimated to be between 0.4 percent and 1.9 percent of total production; under the high energy growth case, these losses would be between 2.0 and 9.3 percent. In 1976, the direct forest loss from air pollution is projected to have been from 0.7 to 3.4 percent of the total production. It also should be noted that evidence suggests that insect damage is more prevalent in areas of air pollution in comparison to the damage in relatively cleaner areas of the ORBES region. However, such damage is not taken into account in these figures.

MORTALITY. As discussed in section 4.6, substantial controversy exists about the quantification of deaths related to air quality. Some researchers believe that only total suspended particulates can be related firmly to increased morbidity and mortality and then only to cardiovascular disease, not to respiratory disease. Many other researchers believe, however, that a growing body of epidemiological evidence exists to support the hypothesis that the annual average exposure to sulfates--or something closely related to them--results in an increased mortality rate.

If the damage functions that were derived under the base period assessment (see section 4.6) are corrected for the projected particulate emissions of each scenario, damage functions ranging from 0-0.36 to 0-3.24 are obtained per 1000 megawatts. (The damage functions derived for the base period range from 0 to 3 cardiovascular deaths per 1000 megawatts of coal-fired electrial generation.)

Based on the corrected damage functions, between 0 and 1555 cardiovascular deaths are projected to occur under the base case from 1975 to 2000 because of particulate emissions from coal-fired generation in the ORBES region. The strict environmental control case would result in about the same range of cumulative particulate deaths. However, under the SIP noncompliance case (which has the highest corrected damage function), the number of particulate deaths related to coal-fired generation between 1975 and 2000 would range from 0 to 4072. This latter range is about 162 percent higher than the range for the base case.

Cumulative sulfate-related deaths between 1975 and 2000 also were projected for the coal-dominated scenarios.[10] Such cumulative sulfate-related deaths are dependent upon which damage function in the range of 0 to 9 is used per 100,000 persons exposed per microgram of sulfates per cubic meter. If a rate of 3 is used, it again becomes clear that the magnitude of utility emissions is a dominant factor since the strict control case would result in the fewest such cumulative deaths (109,000), while the noncompliance case and the high growth case would result in the most such deaths (about 218,000 and 184,000, respectively). Such cumulative deaths under the latter two scenarios also would be nearly 34 and 13 percent higher, respectively, than would the deaths under the base case (163,000). However, as stated in section 4.6, the major usefulness of such damage functions is not in the accuracy of the absolute values of the estimated health impacts, but in the comparisons among the various scenarios that these values make possible.

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[10] For discussions of the controversy surrounding sulfate-related death projections, see Maurice A. Shapiro and A.A. Sooky, Ohio River Basin Energy Study: Health Aspects (ORBES Phase II); Edward P. Radford, Impacts on Human Health from the Coal and Nuclear Fuel Cycles and Other Technologies Associated

6.2 Economic Impacts Related to Air Quality Impacts

The costs to the utilities and to the consumer of the possible reductions in emissions and other air-related impacts also were projected for the five coal-dominated scenarios as well as for the least sulfur dioxide emissions variation and the high electrical energy growth case with a 35-year lifetime variation.[11] Agricultural monetary losses also were estimated for three scenarios--the base case, the SIP noncompliance case, and the high electrical energy growth case.[12] Knowing these costs permits comparisons to be made between the scenarios in terms of the social benefits derived from reduced emissions versus the economic impacts of such reductions.

UTILITY COSTS. Figure 6-7 charts the costs to the utilities of installing new coal-fired generating capacity, of installing pollution control devices on these new units, and of retrofitting existing units.[13] As shown in the figure, the base case, the strict environmental control case, and the SIP noncompliance case would lead to the same capital costs exclusive of pollution control costs. Pollution control costs, however, would differ. The

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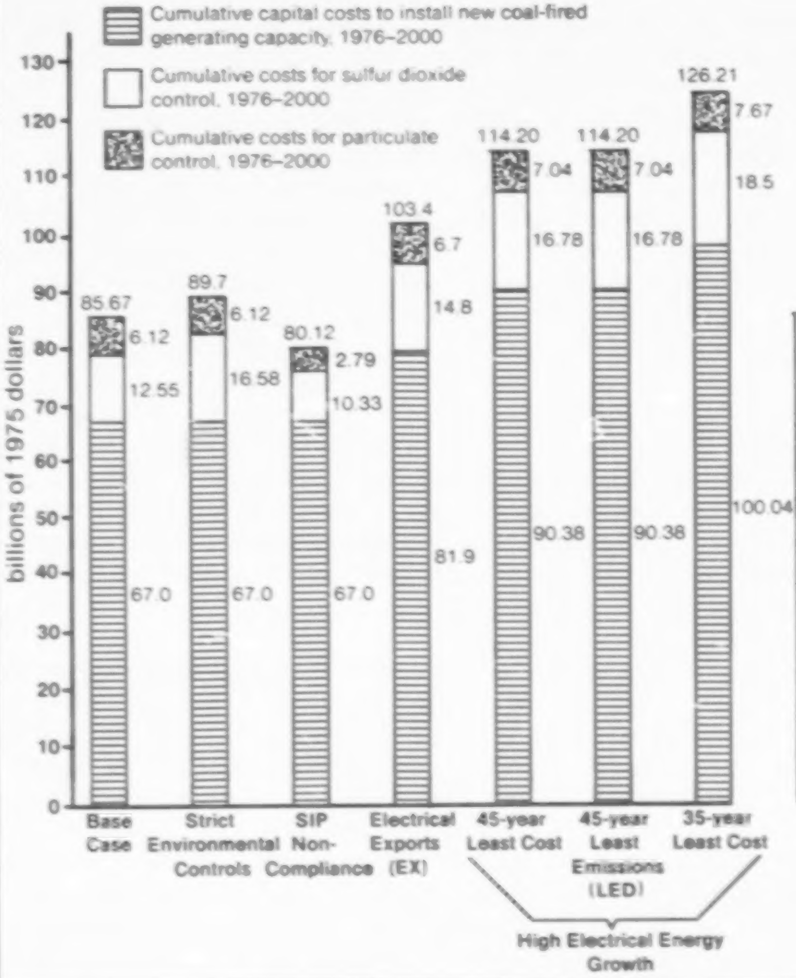
with Electric Power Generation (ORBES Phase II); and Leonard D. Hamilton, "Areas of Uncertainty in Estimates of Health Risks," in Symposium on Energy and Human Health: Human Costs of Electric Power Generation (ORBES Phase II).

[11] For a discussion of all these costs, see Teknekron Research, Inc., Selected Impacts of Electric Utility Operations in the Ohio River Basin.

[12] See Walter P. Page, James Ciecka, and Gary Arbogast, Estimating Regional Losses to Agricultural Producers from Airborne Residuals in the Ohio River Basin Energy Study Region, 1976-2000 (ORBES Phase II).

[13] The cumulative capital costs shown in figure 6-7 include only the costs of the generating capacity and the pollution control equipment installed

Figure 6-7
Cumulative Capital Costs, Coal-Dominated Scenarios, 1976–2000



Cumulative sulfur dioxide and particulate control costs

Scenario	costs billion $	% total costs
BC	18.67	21.8
SEC	22.7	25.3
SIP-N	13.12	16.4
EX	21.5	20.8
HEG	23.82	20.9
LED	23.82	20.9
35-Year	26.17	20.7

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in the ORBES region between 1976 and 2000. The capital costs required for units coming on-line after 2000 are excluded. However, these costs are included in the calculations of the price of electricity and required revenues since expenditures for these units begin before the year 2000.

differences in pollution control costs among these three scenarios would result entirely from the retrofitting of existing SIP plants with pollution control devices. Thus, the total cumulative pollution control costs for the base case would be higher than those for the noncompliance case because about one-third of existing capacity would be retrofitted under the base case. Under the strict control case, on the other hand, almost all of the existing capacity would be retrofitted, resulting in the highest cumulative pollution control costs of the three scenarios.

The high electrical energy growth case and its variations and the electrical exports case would lead to higher costs to the utilities than would the three scenarios discussed above. These higher costs would result because of the installation of both additional generating capacity and the pollution control devices on this new capacity. Thus, if the proportion of pollution control costs to total capital costs is examined, the base case and the high growth case are similar: under both scenarios, pollution control costs would total about 21 to 22 percent of the total costs. It should be noted, however, that these total capital costs do not reflect the operating costs. The operating costs are included in the calculation of the price of electricity, which reflects all the costs borne by the utilities each year. Thus, for example, while the high growth scenario and the high growth least emissions variation are projected to have the same capital costs, their operating costs would differ: the least emissions dispatching variation would entail the increased operation of pollution control devices and the burning of greater quantities of cleaned or low-sulfur coals.

CONSUMER COSTS. The direct costs to the consumer would increase regardless of scenario (see table 6-7). In the short run, however, some scenarios might result in a faster increase in the price of electricity (see figure 6-8). Several observations can be made about the electricity prices and their rate of increase. For one, between 1976 and 1985, the price of electricity would rise according to the added costs of complying with SIP emission limits, paying for rising fuel and capital costs, and meeting electricity demand. Thus, as figure 6-8 indicates, the price of electricity between 1976 and 1985 would rise similarly when nearly the same degree of compliance is assumed--that is, under all the scenarios but the SIP noncompliance case. The strict environmental control case, however, would result in the greatest increase in electricity prices since complying with stricter SIP limits would cost the utilities more. The price of electricity under the SIP noncompliance case, of course, would reflect the absence of such control costs.

Between 1985 and 1995, the increases in electricity prices depend on the electricity demand growth rate, capacity replacement, and capacity expansion. Since the base case, the strict control case, and the noncompliance case assume nearly the same replacement, expansion, and growth rates, the price of electricity would rise little between these years under these scenarios.

Table 6-7
Electricity Prices and Cumulative Revenues, ORBES Region, Coal-Dominated Scenarios, 1976–2000

	Price of Electricity (1975 ¢/kWh)					Cumulative Revenues
Scenario	1976	1985	1990	1995	2000	(billions of 1975 $)
Base Case	2.58	3.87	3.93	4.18	4.64	525
Strict Environmental Controls	2.58	4.21	4.07	4.30	4.71	544
SIP Noncompliance	2.58	3.10	3.52	3.87	4.44	475
High Electrical Energy Growth	2.58	3.80	4.11	4.53	5.53	617
High Electrical Energy Growth, 35-Year Unit Life	2.58	3.80	4.27	4.82	5.70	639
High Electrical Energy Growth, Least Emissions Dispatch	2.58	3.86	4.19	4.60	5.60	626

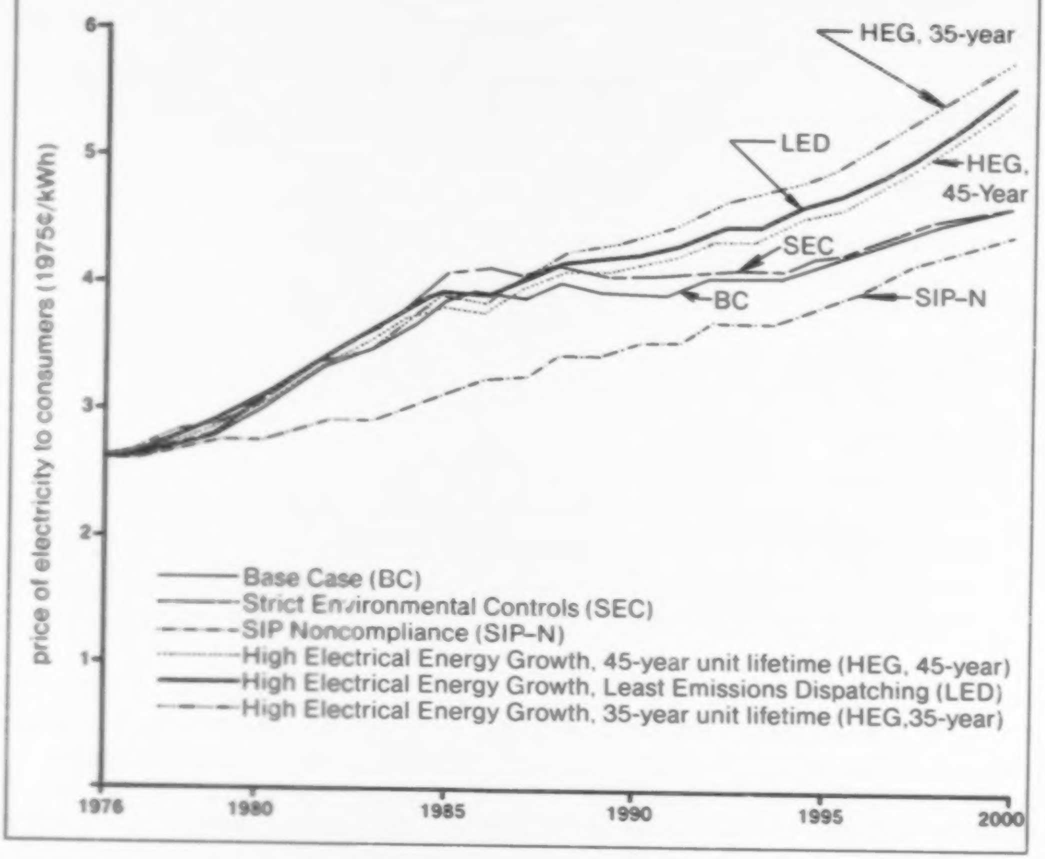
Note: No data available for electrical exports case.

Under the high growth scenario and its variations, however, the price of electricity would rise between 1985 and 1995 since more capacity expansion is projected under these scenarios. The higher operating costs of least emissions dispatching also are reflected in the higher price of electricity under this variation.

Between 1995 and 2000, all scenarios would show a rise in the price of electricity. This increase would result because additional generating units would have to be constructed to satisfy electricity demand after the year 2000 and because a significant number of SIP units would retire during these years and would have to be replaced.

Because some scenarios would cause electricity prices to be higher in the short run, cumulative costs to consumers between 1976 and 2000 give a better idea of total consumer costs than does the price of electricity in a given year. Under the base case, such cumulative revenues required from consumers would total $525 billion (in 1975 dollars, or approximately $709 billion in 1979 dollars). Compared to the base case revenues, the cumulative revenues required under the strict environmental control case would be about 4 percent

Figure 6-8
Electricity Prices in the ORBES Region, Coal-Dominated Scenarios



higher, while the revenues required under the SIP noncompliance case would be about 10 percent lower. A high electrical energy growth rate would require about 18 percent more more revenues than would the base case. Of the two high growth variations, the 35-year variation would require the most revenues (about 21 percent higher than for the base case), while the revenues required for least emissions dispatching would be about 19 percent higher than for the base case.

MONETARY CROP LOSSES. The agricultural monetary losses that would occur because of sulfur dioxide and oxidants follow some of the same patterns as the physical crop losses. First, monetary losses due to oxidants would constitute virtually all (about 99 percent) of the economic losses due to oxidants and sulfur dioxide under the three scenarios examined: the base case, the SIP noncompliance case, and the high electrical energy growth case. In addition, agricultural monetary losses related to sulfur dioxide emissions would be similar under the three scenarios examined (less than 1 percent of the total monetary losses). Also, the total agricultural monetary losses would be concentrated in certain ORBES state portion (Illinois, Indiana, and Ohio) regardless of scenario. Finally, the high growth case would result in the highest cumulative agricultural monetary losses ($8.4 billion in 1975 dollars, or approximately $11.3 billion in 1979 dollars). The base case and the SIP noncompliance case would result in about the same cumulative agricultural monetary losses ($7 billion in 1975 dollars, or approximately $9.5 billion in 1979 dollars).[14]

6.3 Other Impacts Related to Expanded Capacity

LAND. As mentioned in the first paragraph of this chapter, the impacts of an expanded regional generating capacity on land use conversion and the number of terrestrial ecosystem units would be about the same under three of the coal-dominated scenarios--the base case, the strict environmental control case, and the SIP noncompliance case--since their generating capacity is about the same and their siting patterns somewhat similar (see tables 6-8 and 6-9).[15] However, although regionwide impacts would be about the same, impacts at the state level would vary slightly among these scenarios.

The high electrical energy growth case and the electrical exports case would entail larger generating capacities than the three other coal-dominated scenarios. Thus, the amount of land converted and the terrestrial units assessed would rise accordingly: both would be about 30 percent higher under the high growth case than under the base case; under the exports case, land conversion and terrestrial units would be about 17 percent higher than under the base case.

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[14] For a discussion of agricultural losses, see Page, Ciecka, and Arbogast, Estimating Regional Losses to Agricultural Producers.

[15] As discussed in section 4.4, land use refers to the amount of land that must be converted to install the generating capacity of each scenario. Terrestrial ecology refers to the forest lands, Class I and II soils, endangered species, and natural areas that might be affected given this land use conversion. For a fuller discussion of these two aspects, see J.C. Randolph and W.W. Jones, Ohio River Basin Energy Study: Land Use and Terrestrial Ecology (ORBES Phase II).

Table 6-8
Land Conversion for New Electrical Generating Facilities, Coal-Dominated Scenarios, 1976–2000

	Scenario				
State Portion	**Base Case**	**Strict Environmental Controls**	**SIP Noncompliance**	**High Electrical Energy Growth**	**Electrical Exports**
			(acres)		
Illinois	28,528	30,717	28,528	31,841	28,528
Indiana	39,540	40,643	39,540	48,377	39,540
Kentucky	36,433	36,431	36,433	49,687	36,433
Ohio	31,572	31,543	31,572	44,884	45,930
Pennsylvania	27,990	27,990	27,990	30,197	33,513
West Virginia	19,806	19,805	19,806	31,959	31,961
ORBES Region Total	183,869	187,129	183,869	236,945	215,905

Table 6-9
Terrestrial Ecosystem Assessment Units, Coal-Dominated Scenarios, 1976–2000

	Scenario				
State Portion	**Base Case**	**Strict Environmental Controls**	**SIP Noncompliance**	**High Electrical Energy Growth**	**Electrical Exports**
Illinois	356	390	356	442	378
Indiana	451	458	451	533	444
Kentucky	266	268	266	396	274
Ohio	305	300	305	427	434
Pennsylvania	270	277	270	350	330
West Virginia*	156	164	156	249	257
ORBES Region Total	1804	1857	1804	2397	2117

*No substate endangered vertebrate species data available

EMPLOYMENT. More power plant construction and operation workers would be employed under the high electrical energy growth case and the electrical exports case than under the three other coal-dominated scenarios.[16] In fact, such employment would rise dramatically under these two scenarios between 1983 and 1987, although the high growth case would require more workers than the exports case (see figure 6-9).

The rapid changes that could occur under the high growth case might result in short-term labor shortages followed by a surplus of labor as experienced workers have a choice of jobs and then few choices. Moreover, shortages of the skilled labor necessary to power plant construction and operation--such as boilermakers, pipefitters, and electricians--might accompany the high growth case. In general, however, skilled labor shortages would not be a major problem for the region under any of the other coal-dominated scenarios, although local shortages might occur.

Annual regional coal production and coal-mining employment would increase from the 1974 levels under the base case, the strict control case, and the electrical exports case.[17] However, annual coal production would be much higher in 2000 under the electrical exports case than it would be under the two other scenarios. Thus, regional mining employment would rise similarly under the base case and the strict control case, from a minimum of 36 percent to a maximum of about 226 percent, depending on the county. Such employment would increase from a minimum of 42 percent to a maximum of 270 percent under the electrical exports case. It also is projected that at least 79 to 88 of the 152 ORBES-region counties with a concentration in coal mining would experience boom-town effects (growth over 200 percent) under all three of these scenarios.

HEALTH. Under all of the coal-dominated scenarios, the health impacts related to supplying coal to ORBES-region power plants would increase.[18] This increase would result because, under all scenarios, utility coal consumption would be higher than currently. In 1985, the health impacts in the coal-mining and coal-processing sectors would be the same under all coal-dominated scenarios. In 2000, three of the scenarios--the base case, the strict

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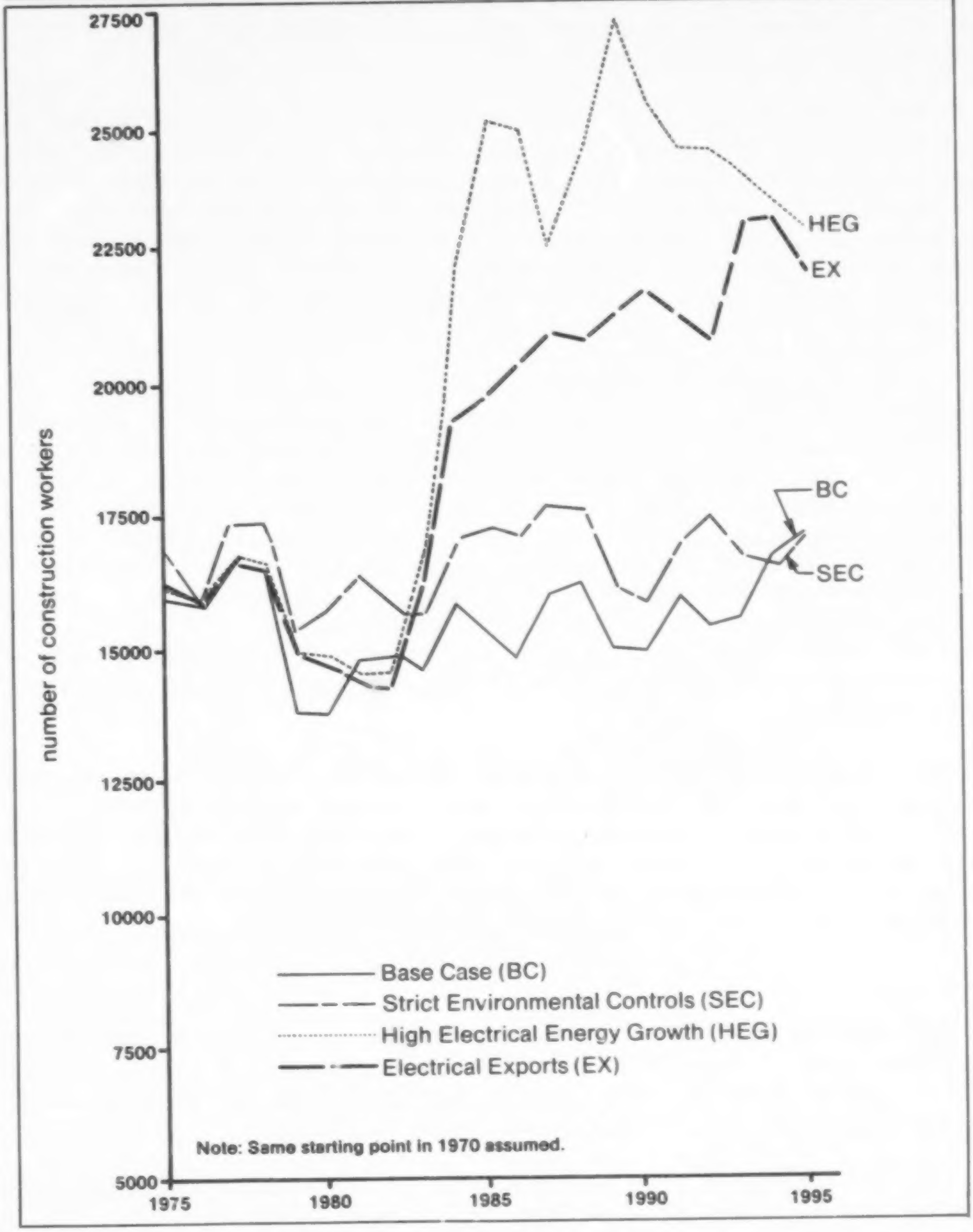
[16] For projections of regional power plant construction and operation employment and of regional coal-mining employment, see Steven I. Gordon and Anna S. Graham, Regional Socioeconomic Impacts of Alternative Energy Scenarios for the Ohio River Basin Energy Study Region (ORBES Phase II).

[17] For coal production estimates, see Donald A. Blome, Coal Mine Siting for the Ohio River Basin Energy Study (ORBES Phase II).

[18] See Shapiro and Sooky, Ohio River Basin Energy Study: Health Aspects.

Figure 6-9
Construction Workers, Coal-Dominated Scenarios, 1975–95



Note: Same starting point in 1970 assumed.

environmental control case, and the SIP noncompliance case--would result in similar health impacts in these sectors, while the high electrical energy growth case and the electrical exports case would result in impacts about 17 percent higher. The health impacts in the coal transportation sector were analyzed only for the base case and the strict control case and only for the year 2000. Both cases would result in an increase in the fatalities associated with the transportation of coal to ORBES-region electrical generating facilities. Injury rates, however, would be about the same as currently since railroad injuries are projected to decline at a greater rate than fatalities.

WATER. All of the coal-dominated scenarios would result in aquatic habitat impacts very similar to those that could have occurred in 1976 under 7-day-10-year low flow conditions.[19] Thus, whether historic municipal and industrial growth continues, or whether high or base case electricity demand occurs, the region already appears to have the potential to experience its most serious aquatic habitat impacts under 7-day-10-year low flow conditions.[20] However, although aquatic habitat impacts would be about the same under all coal-dominated scenarios, some rivers would register changes in their water quality indices under the strict control case and the high growth case--indicating that a river perhaps would experience slightly less or slightly more stress than it would under the base case. Under the high growth case, in particular, these incremental changes in the water quality index would be due to power plant siting.

Background Concentrations. The same aquatic impacts would occur under the coal-dominated scenarios as in 1976 because of the high pollutant concentrations that already exist in the region (called background concentrations). As noted in section 4.5, almost all of the 24 streams studied in detail would have violated several of the study's reference concentrations under 7-day-10-year low flow at some point in 1976. Furthermore, the overwhelming majority of these high background concentrations are estimated to be geochemical or to come from nonpoint sources. Since it is considered unlikely that nonpoint sources could be brought under control during the time frame of this study, background levels in the ORBES streams were projected to remain constant between 1975 and 2000 under all scenarios except the strict environmental control case. Under the strict control case, it was assumed that background levels will be reduced by half by the year 2000. However, even if such a reduction were to occur, it is projected that aquatic habitat impacts would remain unchanged although water quality impact indices might improve slightly. The results under the strict control case thus suggest that background levels are so high that they would have to be reduced more than half to make a difference in aquatic habitat impacts.

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[19] As discussed under base period conditions (section 4.5), the concept of 7-day-10-year flow is a parameter commonly used in river basin management and water quality assessments, primarily as a worst case decision tool or parameter. The water quality analysis carried out for ORBES is reported in Clara Leuthart and Hugh T. Spencer, Fish Resources and Aquatic Habitat Impact Assessment Methodology for the Ohio River Basin Energy Study (ORBES Phase II).

[20] The five coal-dominated scenarios assume the use of cooling towers. If once-through cooling were to be used, however, impacts could be much severer. Under the base case and the electrical exports case, a variation that assumed once-through cooling on the Ohio River main stem was examined. This variation indicates that if such a cooling alternative were used, serious impacts would result. See sections 7.3.2 and 11.3 for a discussion of the impacts under this variation.

Pollutant Loadings. The influence of these background concentrations is further indicated when the pollutant loading assumptions of these scenarios are compared. Under all of the coal-dominated scenarios except the strict environmental control case, power plant effluents were not limited. Along with its assumption of reduced background concentrations, the strict control case assumes that energy conversion facilities will limit effluents to 5 percent of base case levels. However, a comparison of the strict control case with the other coal-dominated cases--the base case, for example--reveals little difference because of the loading assumptions. Although the water quality indices would improve slightly on all rivers under strict controls, protection levels and aquatic habitat impacts would remain the same as under the base case on all but four rivers. If the impacts under the strict control case then are compared to those that could have occurred in 1976, only two rivers would register changes from 1976 protection levels and aquatic habitat impacts. Thus, since loading is not a significant factor, background concentrations appear mainly responsible for the substantial impacts that could occur under 7-day-10-year low flow conditions.

POWER PLANT CONSUMPTION. Power plant consumption would be important on those of the region's smaller streams where little municipal and industrial consumption occurs and where the river's flow under 7-day-10-year low flow conditions would be curtailed drastically. However, if background concentrations were not so high on these small streams, power plant consumption might have little impact. Thus, once again the high background levels are more important than the consumption source.

AFFECTED STREAMS. Of the coal-dominated scenarios, the high growth case would affect the most small streams in the region as well as a number of medium size streams since a large number of units must be sited under that case. Under the high growth case, six rivers would experience higher water quality impact indices because of additional capacity, although these rivers still would register the same protection levels and aquatic habitat impacts as they did under the base case. However, three small streams under the high growth case--the Big Sandy, the Great Miami, and the Little Miami--would register drastic impacts and "D" protection levels with the siting of two or more units on each river.

The impacts on these small streams suggest that alternative siting or technology could alleviate almost all of the impacts on water quality related to power plants under all scenarios. There is, however, one, perhaps significant, problem with alternative siting of power plants. Although water quality would be protected, air quality would suffer since most of the suitable alternative sites in terms of water quality are located along the Ohio River main stem, where air quality problems exist. A further concentration of power plants along this corridor thus could exacerbate these air quality problems.

What can be done to avoid the combined effects of natural forces and high background concentrations is harder to pinpoint, especially since it is unlikely that nonpoint sources can be brought under control. Preventing the rather minor impacts related to power plants would necessitate the tradeoff just discussed. Avoiding the potentially significant impacts of municipal and industrial consumption also would involve tradeoffs. For example, a number of rivers would not be available for growth of any kind if regulatory bodies were to implement siting restrictions that would prohibit the siting of any entity that consumed water along streams having 7-day-10-year low flows less than 100 cubic feet per second. Such restrictions would result in a very limited number of sites for industry, especially for power plants. Thus, as this brief outlining of some possible steps and their limitations suggests, improvements in water quality may require some environmental, social, and economic tradeoffs that would have their own repercussions.

In the chapters that follow, each of the five ORBES coal-dominated scenarios is discussed in detail in terms of the following impact areas: air, land, water, employment, and health. Impacts of the base case are considered in chapter 7; impacts of the strict environmental control case, in chapter 8; impacts of the SIP noncompliance case, in chapter 9; impacts of the high electrical energy growth case, in chapter 10; and impacts of the electrical exports case, in chapter 11. The base case impacts are compared with base period conditions in the ORBES region, while the impacts of the other scenarios are compared with those of the base case.

7. Impacts of the Base Case

In this chapter the air, land, water, employment, and health impacts that could be expected under the base case are identified and contrasted with conditions in the ORBES region during the mid-1970s (see chapter 4). Under the base case, current environmental standards are applied to present and future sources of pollution. With regard to air, for example, controls are defined as the application of standards set forth in state implementation plans (SIPs), new source performance standards (NSPS), and revised new source performance standards (RNSPS). The average annual electricity demand growth rate is 3.13 percent under the base case, and this rate results in an installed regional electrical generating capacity of 153,245 megawatts electric in the year 2000. Ninety-five standard coal-fired units are sited in the study region after 1985 under the base case. For a more detailed discussion, see chapter 5.

7.1 Air

Under base case environmental regulations, utility sulfur dioxide and particulate emissions would decrease through the year 2000 from the 1976 emission levels, while utility nitrogen oxide emissions would increase.[1] Both annual average and episodic concentrations of sulfur dioxide and sulfates due to utility emissions also would decrease substantially. Electricity prices, however, would increase dramatically over the 1976 price.

SULFUR DIOXIDE EMISSIONS. A definite trend is evident with regard to regional utility sulfur dioxide emissions under the base case: total utility emissions would follow a pattern similar to emissions from SIP-governed units (see figure 7-1a). The assumption that SIP units will achieve full compliance by

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[1] For projections of air pollutant emissions and concentrations under the base case, as well as under the other ORBES scenarios, see James J. Stukel and Brand L. Niemann, Documentation in Support of Key ORBES Air Quality Findings; Teknekron Research, Inc., Air Quality and Meteorology in the Ohio River Basin: Baseline and Future Impacts; and Teknekron Research, Inc., Selected Impacts of Electric Utility Operations in the Ohio River Basin (1976-2000): An Application of the Utility Simulation Model (vols. I, II, and III, respectively, of James J. Stukel, ed., Ohio River Basin Energy Study: Air Quality and Related Impacts (ORBES Phase II)).

Figure 7-1a
Electric Utility Sulfur Dioxide Emissions in the ORBES Region, Base Case, by Unit Type

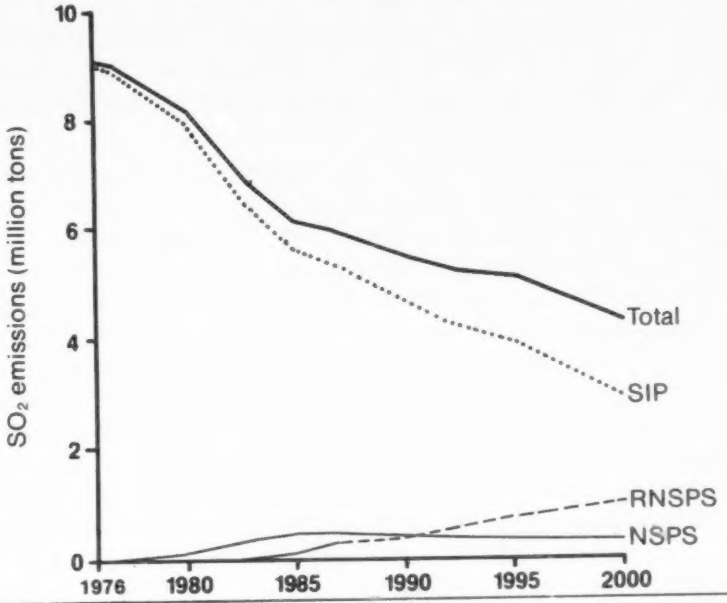
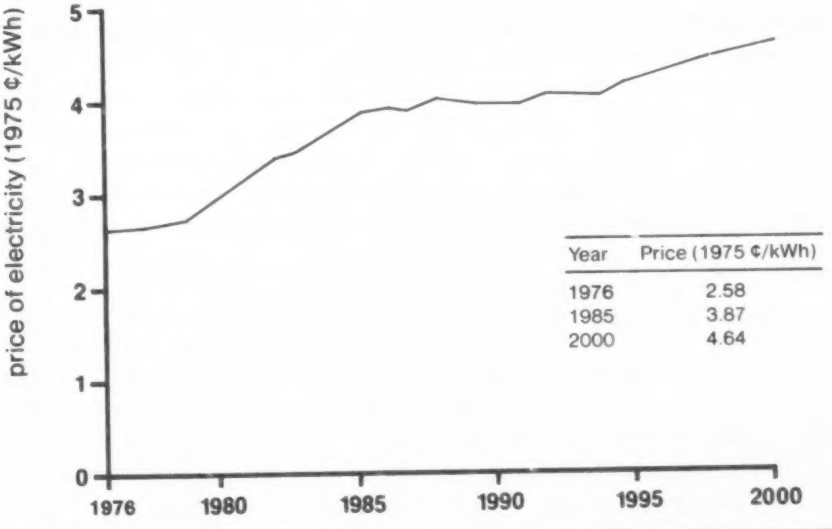


Figure 7-1b
Price of Electricity in the ORBES Region, Base Case



Year	Price (1975 ¢/kWh)
1976	2.58
1985	3.87
2000	4.64

1985 would reduce total utility emissions as well as emissions from SIP units between 1976 and 1985. Between 1985 and 2000, both total utility and SIP emissions would decline because of the assumption that SIP units would be retired after 35 years. However, such retirements after 1985 also would result in an increase in emissions from RNSPS units as more such units replace the retired SIP plants. In terms of absolute numbers, regional utility sulfur dioxide emissions in 1976 totaled 8.94 million tons. By 1985, sulfur dioxide emissions from all electrical generating units in the ORBES region (those regulated by SIPs, NSPS, and RNSPS) would decrease 32 percent--to 6.1 million tons. By 2000, they would decrease 51 percent--to 4.35 million tons.[2]

Despite the decrease in SIP emissions and the increase in RNSPS emissions, SIP emissions still would be the key to further reductions of the emissions projected under the base case. RNSPS units already are very clean units, removing approximately 90 percent of their potential sulfur dioxide emissions. In fact, five or six RNSPS units produce about the same amount of sulfur dioxide emissions as an average complying SIP unit that supplies the equivalent amount of electricity. As a result of the comparative "dirtiness" of SIP units, in the year 2000 they would account for approximately 67 percent (or 2.93 million tons) of all utility sulfur dioxide emissions in the ORBES region. However, these units would account for only 24 percent of the electricity generated. (In 1985, by contrast, when emissions from SIP units would account for 92 percent (or 5.6 million tons) of total utility sulfur dioxide emissions, these units would account for 68 percent of the total regional electrical generation.) It is clear, therefore, that although SIP standards would reduce emissions from the 1976 levels, other strategies would be required to achieve a more balanced emission-generation ratio between 1985 and 2000.

Nonutility sulfur dioxide emissions in the ORBES region would increase by about 30 percent between 1975 and 2000, based on some recent, highly approximate projections. As a result of such increases, nonutility emissions would make up a larger fraction of the total sulfur dioxide emissions in 2000 than they did in 1975. Thus, while nonutility emissions accounted for approximately 20 percent of all sulfur dioxide emissions in 1975, these emissions would account for approximately 29 percent of all sulfur dioxide emissions in 2000 under the base case.[3] As a result of the increased nonutility emissions and the decreased utility emissions, total sulfur dioxide emissions in the ORBES region would decrease by about 40 percent by the year 2000 from the total emissions of this pollutant in 1975.

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[2] A higher power plant capacity factor and a lower BTU content for coal were assumed in the utility simulation model analysis than was assumed by other ORBES researchers. The combined effect of these differences in assumptions is a higher coal use estimate in the ORBES region in the year 2000. For a discussion of these different assumptions, see Teknekron Research, Inc., Selected Impacts of Electric Utility Operations.

PARTICULATE EMISSIONS. Total regional particulate emissions would continue to be dominated by nonutility emissions under the base case, as they were during the base period. Utility particulate emissions would decrease dramatically. Annual utility particulate emissions in the ORBES region, which totaled 1.38 million tons in 1976, would decrease 82 percent by 1985 and 86 percent by 2000 (to 250,000 tons in 1985 and to 190,000 tons in 2000). Nonutility particulate emissions in the ORBES region also would decrease (by about 60 percent) under the base case between 1976 and 1985, again according to some recent, highly approximate projections. However, between 1985 and 2000, regional nonutility particulate emissions would increase by about 30 percent from their 1985 levels. (The different growth rates assumed for the utility and nonutility sectors result in the decrease in utility emissions and the increase in nonutility emissions after 1985.) Thus, since nonutility emissions account for about 75 percent of the total regional particulate emissions, total particulate emissions would decrease about 60 percent by 1985 from the 1976 levels and would increase about 14 percent during the period between 1985 and 2000.

NITROGEN OXIDE EMISSIONS. Annual utility emissions of oxides of nitrogen, on the other hand, would increase between 1976 and 2000. Such emissions would total 1.71 million tons in 1985, an increase of 15 percent over the 1.49 million tons in 1976. By 2000, annual utility nitrogen oxide emissions in the ORBES region would total 2 million tons, a 34 percent increase. As discussed in chapter 6, utility nitrogen oxide emissions would increase because no SIP standards for oxides of nitrogen exist in the ORBES region, except in the urban areas of Illinois. Thus, the greater the electricity demand growth, the greater the emissions.

SULFUR DIOXIDE AND SULFATE CONCENTRATIONS. As a result of decreased utility sulfur dioxide emissions under the base case, regional utility emissions should contribute less to regional sulfur dioxide and sulfate concentrations by the year 2000 than they contributed during the base period. However, the ratio of the lower ORBES region's contribution to sulfur dioxide and sulfate concentrations in the upper region is not likely to change under the base case, or under any scenario, from the 1976 ratio.[4]

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[3] Nonutility emissions are estimated in Teknekron Research, Inc., Air Quality and Meteorology in the Ohio River Basin.

[4] For a discussion of concentration projections, see Teknekron Research, Inc., Air Quality and Meteorology in the Ohio River Basin.

If the same conditions of extremely persistent winds were to occur under the base case as those that occurred during the August 27, 1974, sulfate episode, the utility-related sulfur dioxide and sulfate concentrations would be reduced significantly in both 1985 and 2000.[5] Specifically, utility-related sulfur dioxide concentrations in the area that experienced the highest concentrations in 1976 would total 65.2 micrograms per cubic meter (31 percent lower) in 1985 and 48.2 micrograms per cubic meter (49 percent lower) in 2000. Sulfate concentrations in this high concentration area due to all regional utility emissions would total 30 micrograms per cubic meter (25 percent lower) in 1985 and 19.7 micrograms per cubic meter (51 percent lower) in 2000. About 12 micrograms per cubic meter of these sulfate concentrations in the year 2000 would come from utility emissions in just the lower ORBES region. However, the contribution by the lower region to the upper region would be about 60 percent lower than the amount contributed by the lower region to the upper region during the August 27 episode.

Annual utility-related sulfur dioxide and sulfate concentrations in the ORBES region also would decrease under the base case from the 1976 regional utility-related concentrations, especially in the area with the highest annual concentrations in 1976. In 1985 under the base case, the annual sulfur dioxide concentration in this high concentration area would be 18.55 micrograms per cubic meter (or 28 percent lower), and the annual sulfate concentration would be 6.7 micrograms per cubic meter (or 27 percent lower). By 2000 under the base case, the annual sulfur dioxide concentration in this high concentration area should have decreased about 50 percent from the 1976 levels--to 12.94 micrograms per cubic meter--and the annual sulfate concentration, about 49 percent--to 4.7 micrograms per cubic meter.

Figures 7-2 and 7-3 depict the significant improvements throughout the region in annual utility-related concentrations under the base case. Figure 7-2 compares the 1976 sulfur dioxide concentrations with the projected 2000 sulfur dioxide concentrations. As can be seen, the area affected by the highest sulfur dioxide concentrations would be significantly smaller under the base case, although the general location of the highest sulfur dioxide concentrations would remain about the same. Figure 7-3 compares the annual average sulfate concentrations in 1976 and 2000 and shows the extensive improvements projected in such utility-related concentrations both within and outside of the region.

Since nonutility sulfur dioxide emissions would increase between 1976 and 2000, the annual average concentrations attributable to such emissions also

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[5] The August 27, 1974, episode, discussed in section 4.3, exemplifies the most frequently occurring type of sulfate episode. Such an episode involves a simple flow pattern of extremely persistent winds blowing from the west to the east over the ORBES region.

Figure 7-2
Annual Average Sulfur Dioxide Concentrations, Electric Utility Contribution

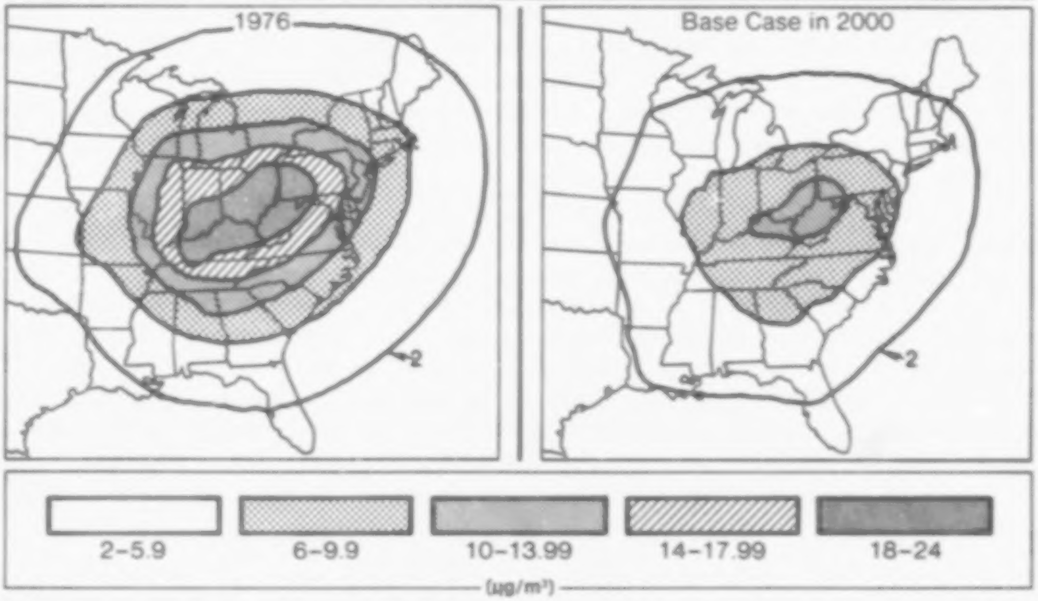
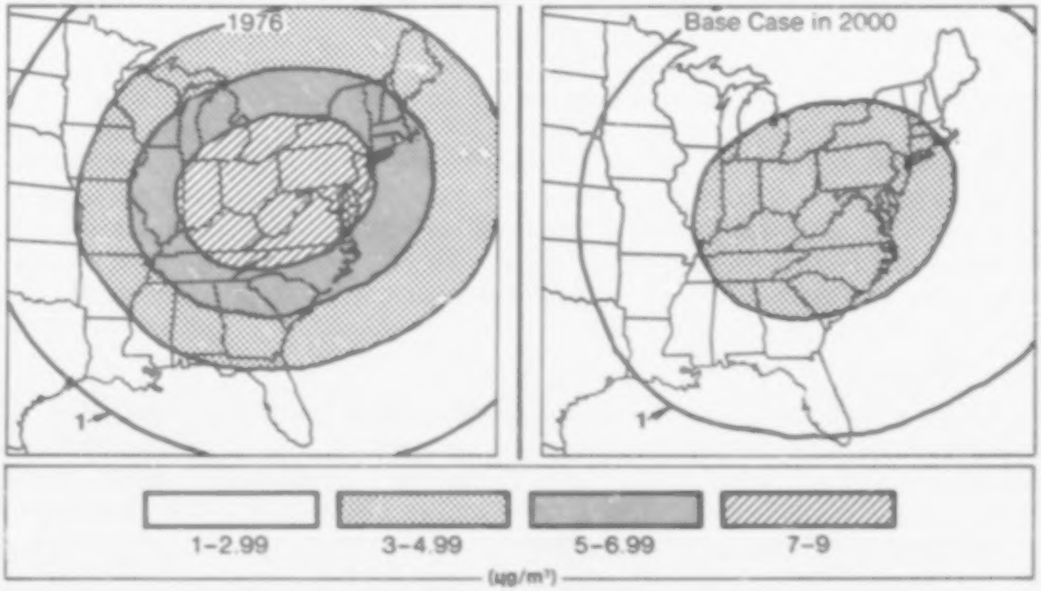

1976
2
Base Case in 2000
2
2-5.9
6-9.9
10-13.99
14-17.99
18-24
(µg/m³)

Figure 7-3
Annual Average Sulfate Concentrations, Electric Utility Contribution


1976
1
Base Case in 2000
1
1-2.99
3-4.99
5-6.99
7-9
(µg/m³)

would increase. However, since nonutility sulfur dioxide emissions would comprise only about 29 percent of total regional sulfur dioxide emissions in 2000, non-utility-related concentrations would be much lower than the utility-related concentrations. The annual average sulfur dioxide concentrations resulting from nonutility emissions would increase from about 2 micrograms per cubic meter in 1975 to about 4 micrograms per cubic meter in 2000. Between these same years, annual average sulfate concentrations would increase from approximately 1 microgram per cubic meter to approximately 2 micrograms per cubic meter.

UTILITY COSTS. To achieve these significantly reduced emissions and concentrations, total cumulative capital costs for pollution control through the year 2000 would be $18.67 billion (expressed in constant 1975 dollars, or approximately $25.20 billion in 1979 dollars). Of this total, $12.55 billion would be required for the control of sulfur dioxide emissions, and $6.12 billion for the control of particulate emissions.[6] These pollution control costs reflect (1) the costs of retrofitting SIP units with flue gas desulfurization devices (scrubbers) and electrostatic precipitators to meet base case SIP emission limits and (2) the costs of installing these devices on new units.

Cumulative capital costs to install new coal-fired capacity under the base case would total $67 billion (1975 dollars, or approximately $90 billion in 1979 dollars). Thus, the pollution control costs of $18.67 billion would represent approximately 22 percent of the total cumulative capital costs ($85.67 billion) that would be required to achieve the environmental standards and the growth in coal-fired electrical generating capacity projected under the base case.

CONSUMER COSTS. In terms of direct costs to the consumer, the real price of electricity would rise between 1976 and 1985 to 3.87 cents per kilowatt hour, an increase of 4.6 percent per year (see figure 7-1b). This increase reflects several factors: the added costs of achieving base case environmental regulations, rising fuel costs, rising capital costs, and the costs of meeting increased electricity demand.[7] Between 1985 and 2000, the price of electricity would not rise as rapidly, due partly to the lower annual growth rate assumed during this period. As a result, the price of electricity in 2000 would be 4.64 cents per kilowatt hour. Since the price of electricity in 1976 was 2.58 cents per kilowatt hour, base case prices would be 50 percent higher in 1985 and 80 percent higher in 2000.

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[6] The electricity prices and capital costs associated with the ORBES scenarios, including the base case, are discussed in Teknekron Research, Inc., Selected Impacts of Electric Utility Operations. Cumulative capital costs to install projected nuclear-fueled generating capacity under the base case--as well as under all the coal-dominated scenarios--would total $8.3 billion.

[7] It is interesting to note that the increases in coal costs associated with the depletion of reserves in order to produce the anticipated tonnage in

However, electricity prices at one or two points in time do not fully capture the actual costs to the consumer; the price of electricity in a single year is merely a snapshot of the changes that would occur. The cumulative revenues that actually would be required from consumers between 1976 and 2000 better represent the average price differences over this period. Under the base case, the cumulative revenues required during the study period would total $525 billion (in 1975 dollars, or approximately $709 billion in 1979 dollars).

7.2 Land

LAND USE. The single most important factor in terms of total land use conversion under the base case--and indeed under all scenarios--is the growth rate of generating capacity through the year 2000. In general, land resources probably would meet the demand adequately. However, given both land and other siting criteria, the number of suitable sites for generating facilities could be limited by the year 2000.[8]

The land conversion required under the base case between 1976 and 2000 for all new energy-related uses (new generating facilities, new transmission line rights-of-way, and new surface mining for utility coal) would total about 991,000 acres (1548 square miles), or 0.8 percent of the total land in the ORBES region. Of this total, the conversion required for new electrical generating facilities would represent about 19 percent (183,869 acres), and the estimated land use requirement for new transmission line rights-of-way

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the year 2000 are invariant across the base case, the strict control case, and the high growth case. Thus, the production of low-sulfur coal from BOM districts 1 and 3 and from BOM districts 7 and 8 to supply the anticipated demand in 2000 would lead to an increase in coal tonnage costs from depletion of approximately 14 percent and 33 percent, respectively. High-sulfur coal production from BOM districts 2, 4, 6, 10, and 11 and from BOM districts 1 and 3 would lead to increases from such depletion of 40 percent and 78 percent, respectively. For discussion, see Walter P. Page, An Economic Analysis of Coal Supply in the Ohio River Basin Energy Study Region (ORBES Phase II).

[8] See J.C. Randolph and W.W. Jones, Ohio River Basin Energy Study: Land Use and Terrestrial Ecology (ORBES Phase II) for a discussion of energy-related land use. For a discussion of the siting criteria, see Gary L. Fowler et al., The Ohio River Basin Energy Facility Siting Model: Methodology (vol. I) (ORBES Phase II).

would represent 14 percent (or 134,224 acres).[9] Surface mining for utility coal represents the remaining 67 percent. Although the total land conversion required under the base case represents less than 1 percent of the region, conversion at the county level could represent a substantial portion of that county's total acreage.

Of the total land needed for new facilities, the most (21.5 percent) would be taken from the ORBES portion of Indiana and the least (15.2 percent) from the Pennsylvania portion (see table 7-1). In terms of the land types converted to install base case generating facilities by the year 2000, 52 percent would be agricultural lands; 37 percent, forest lands; 2 percent, public lands; and 9 percent, other lands.

Coal Mining. Of the total amount of land required under the base case for the surface mining of coal for regional electrical generation (673,000 acres), 184,000 acres would be affected in the Eastern Interior Coal Province; 489,000 acres would be affected in the Appalachian Province.[10] This acreage affected by surface mining for regional utility coal under the base case would represent 29 percent of the cumulative amount of land (2.32 million acres) required for the surface mining of coal for all purposes between 1976 and 2000.

Under the base case, underground production would increase by the year 2000. Surface-mining production would range from 26 to 60 percent of total production depending on the geographical location. In the base period, the range was between 19 and 98 percent.

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[9] Of the total acres required for new generating facilities under all scenarios, approximately 36.5 percent would be reversibly committed between 1976 and 2000, and approximately 63.5 percent would be irreversibly committed during the same period. Reversible commitments refer to the areas associated with a facility but not affected directly--for example, utility-owned lands at a facility site that are contiguous to but not actually included in the construction area. Irreversible commitments include buildings, fuel and waste storage areas, and associated roads at the construction site. However, the notion of reversible and irreversible is a matter of debate. But the expense and time needed to reverse certain uses of land would be so far beyond the time frame of this project as to be irrelevant. Therefore, for purposes of ORBES, an irreversible land use is defined as one that is at least likely to exist for the normal life of a generating facility, and probably much longer.

[10] For a discussion of surface mining in the ORBES region, see Daniel E. Willard et al., A Land Use Analysis of Existing and Potential Coal Surface Mining Areas in the Ohio River Basin Energy Study Region (ORBES Phase II).

Table 7-1
Land Use Conversion for Electrical Generating Facilities, Base Case, 1976–2000

State Portion	Public Lands	Agricultural Lands	Forest Lands	Other Lands	Total
			(acres)		
Illinois	356	23,046	3,179	1,947	28,528
Indiana	1,009	25,674	9,799	3,058	39,540
Kentucky	313	20,425	12,508	3,187	36,433
Ohio	1,700	13,122	14,175	2,575	31,572
Pennsylvania	1,120	8,315	14,347	4,208	27,990
West Virginia	352	4,598	13,148	1,708	19,806
ORBES Region	4,827	95,920	67,311	15,809	183,869

Land Use Conflict. In general, under the base case--as well as under all scenarios--the probability of conflict between prime agricultural land use, steep slope land use (forested lands or lands recommended for forestation), and surface mining would change little from base period conditions. For example, the low-sulfur coal that supplies SIP-governed units in the ORBES region currently originates, and would continue to originate, in the hills of eastern Kentucky, West Virginia, and Pennsylvania. Therefore, the possibility of conflicts with prime farmland in supplying these plants is small, and the probability of conflict with steep slopes higher. However, because the surface mining of coal for scenario additions would take place in the same state as each sited plant, the surface mining of coal to supply these new units in the ORBES region would be 22 percent more likely to affect prime farmland and 6 percent more likely to affect steep slopes than the mining for existing SIP units.

Land Reclamation. In the year 2000 under the base case, 220,000 acres would be undergoing a two-year reclamation process. Although the Appalachian Coal Province contains more sloping land than does the Eastern Interior Province, reclaimed ecological productivity and land use would vary only slightly under the base case--and, indeed, under all scenarios--from present reclaimed productivity and land use.

The ecological impacts of base case energy-related land use patterns would vary according to the type of impact that is being examined. In general in the year 2000, as compared to base period conditions, less land would be affected by sulfur dioxide concentrations resulting from utility emissions; less crop loss would occur because of utility sulfur dioxide emissions and because of oxidants formed by nitrogen oxide emissions; and more terrestrial ecosystem units (measuring the amount of forest lands and of Class I and II soils and the number of natural areas and endangered species affected) would be assessed.

Under the base case, less land would be affected by utility-related sulfur dioxide concentrations of 130 micrograms per cubic meter in the presence of moderate ozone levels than was affected in 1976.[11] Thus, while the land affected by such concentrations represented 10 percent of the ORBES region in 1976, such concentrations would affect only 4.8 percent of the region in 1985 and only 3 percent of the region in 2000. Similarly, the acreage affected by such concentrations would be lower in each state portion, although the percentage reduction would vary significantly among the state portions.

PHYSICAL CROP LOSSES. Regional agricultural losses due to such utility-related sulfur dioxide concentrations in the presence of moderate ozone levels are estimated not to be as high under the base case as the losses estimated for 1976. In 1985, regional soybean, wheat, and corn losses would result in a combined loss ranging from a minimum of 329,000 bushels to a maximum of 2.3 million bushels; the probable combined loss is estimated to be 1.2 million bushels. In the year 2000, the range for the combined annual losses would be from 248,000 to 1.7 million bushels, with 924,000 bushels representing the probable combined loss.

Under the base case as well as during the base period, agricultural losses due to sulfur dioxide would account for less than 1 percent of the regional losses projected to occur because of sulfur dioxide and ozone. Yet, on a local scale, such as the county, losses related to sulfur dioxide could be significant, and losses to individual farmers substantial.

Regional agricultural losses due to ozone formed from regional nitrogen oxide emissions in combination with other pollutants are estimated to increase through 1985 under the base case. After 1985, however, as the nitrogen oxide emissions of regional transportation sources decrease, regional agricultural losses would decrease dramatically. It is projected, therefore, that after 1985 utility nitrogen oxide emissions will begin to account for a larger percentage of the crop losses than they did in 1976 or 1985 since utility nitrogen oxide emissions are not regulated and would continue to increase through the year 2000.

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[11] For a discussion of the acreage affected by sulfur dioxide concentrations and for crop loss projections, see Orie L. Loucks et al., Crop and Forest Losses Due to Current and Projected Emissions from Coal-Fired Power Plants in the Ohio River Basin (ORBES Phase II). In this analysis, peak load operation was assumed since crops would be most affected by sulfur dioxide concentrations during the summer growing season, when electricity demand is the highest.

In 1985, agricultural losses related to oxidants formed from all regional nitrogen oxide emissions are projected to range from a minimum of 290 million bushels to a maximum of 691 million bushels; the probable loss is estimated to be 412 million bushels. In the year 2000, such agricultural losses are projected to range from 99 million bushels to 358 million bushels, with 172 million bushels representing the probable loss.

It should be noted that soybean losses make up the majority of the agricultural losses attributable to sulfur dioxide and that corn losses make up the majority of the agricultural losses attributable to ozone. Moreover, the percentage of losses in each state portion varies considerably. For both the losses related to sulfur dioxide and those related to ozone, the ORBES state portions of Illinois, Indiana, and Ohio would account for 95 percent of the projected losses.

MONETARY CROP LOSSES. Also projected was the economic impact of these crop losses attributable to utility sulfur dioxide emissions and to oxidants formed from all regional nitrogen oxide emissions. Cumulative regional crop losses between 1976 and 2000 would have a present discounted value of $70 billion (in 1975 dollars, or approximately $95 million in 1979 dollars).[12] Oxidant damages represent virtually all (99.3 percent) of this figure. In terms of the crops examined, soybean dollar losses would represent 54 percent of the total dollar loss figure; corn losses, 42 percent; and wheat losses, 3 percent. Of the ORBES state portions, dollar losses in Illinois and Indiana would account for the majority (about 79 percent) of the probable regional dollar losses, and Illinois, Indiana, and Ohio together would account for about 95 percent.

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[12] Present discounted value represents the cumulative dollar amount between 1976 and 2000 that has been discounted to its value in 1976. The projected cumulative dollar loss also is based on the probable crop loss figures. For minimum and maximum losses, see Walter P. Page, James Ciecka, and Gary Arbogast, Estimating Regional Losses to Agricultural Production from Airborne Residuals in the Ohio River Basin Energy Study Region, 1976-2000 (ORBES Phase II).

FOREST LOSSES. Similar to the crop loss projections, forest losses are projected to increase through 1985 and to decrease thereafter. The estimated annual reduction in forest growth in 1985 due to air pollutants, principally ozone, would be from 1.3 to 6.3 percent of the total production. In 2000, projected annual losses would range from 0.4 to 1.9 percent of total production. The reduction in forest growth projected for 1976 was from 0.7 to 3.4 percent.

TERRESTRIAL ECOLOGY. Between 1976 and 2000 under the base case, terrestrial ecosystem assessment units would increase bv 1804 units over the 1976 total of 1306 units (a 138 percent increase).[13] Among the ORBES state portions, Indiana would experience the largest increase in 2000 (216 percent) from the ecosystem units assigned to that state portion in 1976 (see figure 7-4). The increases in state terrestrial ecosystem units among the other state portions could range from a 101 percent increase in West Virginia to a 161 percent increase in Kentucky.

7.3 Water

The aquatic habitat impacts that would occur in the year 2000 under base case conditions, the ORBES reference concentrations, and 7-day-10-year low

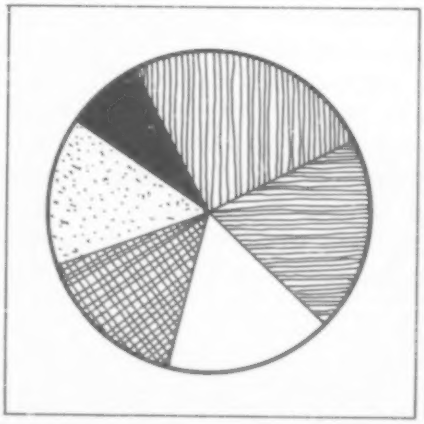

Figure 7-4
Terrestrial Ecosystem Assessment Units, Base Case, by ORBES State Portion

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[13] See Randolph and Jones, Ohio River Basin Energy Study: Land Use and Terrestrial Ecology.

flow were projected for each of the 24 regional rivers selected for detailed analysis. In general, aquatic habitat impacts under the base case would be very similar to the impacts that could have occurred in 1976 under these low flow conditions (see table 7-2).[14] Moreover, as table 7-2 indicates, these aquatic habitat impacts under the base case would be almost entirely the result of high background concentrations alone or in conjunction with municipal and industrial water consumption.[15]

Only two streams--the Big Muddy and the Illinois rivers--are projected to experience aquatic habitat impacts different from those they could have experienced in 1976, and only three streams--the latter two rivers plus the Allegheny--are projected to experience impacts because of high background concentrations and water consumption by power plants. Both of these results would occur either because the stream in question is small and has a very low flow under 7-day-10-year low flow or because a rather large amount of generating capacity was added under the base case to a medium-size stream. The Big Muddy, for example, is one of the region's smaller streams, with only one reach and a flow of 37 cubic feet per second under 7-day-10-year low flow conditions. Thus, as summarized in table 7-2, when 346 megawatts electric are added on this river, drastic aquatic habitat impacts are projected to occur. A rather large capacity (planned units plus scenario additions) is added to the Allegheny and Illinois rivers under the base case. As a result, it is projected that the Illinois would experience heavy aquatic impacts in comparison to the moderate impacts that it would have experienced in 1976 under 7-day-10-year low flow conditions. The Allegheny River, however, would experience the same aquatic habitat impacts as it was projected to experience in 1976, although the water quality index would increase slightly under the base case, indicating that the Allegheny would experience slightly more stress than it would have in 1976.

Although additional generating capacity is added to other streams under the base case, such capacity appears not to cause significant impacts either because the stream is very large or because the impacts of background concentrations and of municipal and industrial consumption far outweigh the impacts that would occur because of power plant consumption. For example,

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[14] Details on water quality and aquatic ecology impacts are provided in Clara Leuthart and Hugh T. Spencer, Fish Resources and Aquatic Habitat Impact Assessment Methodology for the Ohio River Basin Energy Study Region (ORBES Phase II).

[15] For details on water consumption projections, see E. Downey Brill, Jr. et al., Potential Water Quantity and Water Quality Impacts of Power Plant Development Scenarios on Major Rivers in the Ohio Basin (ORBES Phase II).

Table 7-2
Aquatic Habitat Impacts, Base Case, 7-Day–10-Year Low Flow, Year 2000, versus Impacts in 1976, 7-Day–10-Year Low Flow

River	Better (+) Worse (−) Same (0) as 1976 Impacts	Water Quality Impact (range: 0–100)	Base Case Protection Levels	Base Case Aquatic Habitat Impacts	Aquatic Habitat Impacts†	Number of Scenario Additions	Utility-planned Installed Capacity (MWe)
Allegheny	0	32	C	Heavy	E, P	7	5,659
Beaver	0	35	C	Heavy	E, M	3	0
Big Muddy	—	54	D	Drastic	E, P	0	346
Big Sandy	0	39	C	Heavy	E	0	0
Cumberland	0	30	C	Heavy	E	0	0
Great Miami	0	47	C	Heavy	E	0	160
Green	0	38	C	Heavy	E	0	480
Illinois	—	31	C	Heavy	P	8	15,155
Kanawha	0	34	C	Heavy	E, M	0	2,931
Kaskaskia	0	15	B	Moderate	E	0	0
Kentucky		—	*	—	—	0	440
Licking	0	30	C	Heavy	E	0	0
Little Miami	0	45	D	Heavy	E	0	0
Mississippi	0	18	B	Moderate	E	2	566
Monongahela	0	34	C	Heavy	E, M	3	2,470
Muskingum	0	40	C	Heavy	E, C	3	1,826
Ohio River Main Stem	0	41	C	Heavy	E, M	72	42,829
Rock		—	*	—	—	2	0
Salt		—	*	—	—	0	0
Scioto	0	36	C	Heavy	E, M	2	90
Susquehanna		—	*	—	—	1	0
Wabash	0	22	B	Moderate	E, M	4	6,932
White	0	30	D	Heavy	E, M	0	1,535
Whitewater		—	*	—	—	0	160

*Background data unavailable; analysis could not be completed.

†P = power plant water consumption; M = municipal water consumption; E = background concentrations; and C = combined power plant and municipal water consumption.

although 72 units, or 46,800 megawatts electric, were added to the Ohio main stem under the base case in addition to the 42,829 megawatts electric announced by the utilities, aquatic habitat impacts would be the same under the base case in the year 2000 as they could have been in 1976 under 7-day-10-year low flow conditions. As table 7-2 indicates, high background concentrations and municipal and industrial consumption on the main stem overwhelm the contribution of power plant consumption.

To summarize, base case water quality impacts, like the projected 1976 impacts, are primarily the result of the high background concentrations. Thus, such concentrations would have to be lowered to avoid many of the impacts that a natural phenomenon such as 7-day-10-year low flow could cause. However, as discussed in chapter 6, it is deemed unlikely that the major reason for these high background concentrations--nonpoint and geochemical sources--could be brought under control during the time period of this study.

7.3.1 Water Variation

A variation of the base case also was explored in the water quality analysis. In this variation, the water quality impacts of once-through cooling were examined.[16] Except for the substitution of once-through cooling for cooling towers in the 72 units added to the Ohio River main stem under the base case, this variation has the identical assumptions of the base case.

Once-through cooling is an older method of dissipating excess heat that is not converted into electricity, and some plants currently using this method are being retired or converted to newer methods such as evaporative cooling towers. In the once-through cooling process, large quantities of water are removed from a body of water, passed through the plant once so that the temperature of the water is raised slightly, and then returned to the original source. The heated effluents tend to slide along the surface of the water and against the banks, where they enter the water. This mixing pattern does raise the temperature of the water locally, but the temperature usually is dissipated within 10 miles of the point of entry.

At present, 38 power plants along the Ohio River main stem reject heat directly into the river by the once-through cooling method. In 1977, these plants--assuming that they operate at a 50 percent capacity factor--released the equivalent heat value of 51,600 tons of typical bituminous coal. By 1985, the amount of heat rejected into the Ohio River main stem by once-through cooling should be reduced by 11 percent because of planned retirements; by 2000, planned retirements and replacements should reduce the amount by 95 percent. Water withdrawal for the cooling of power plants by 2000 thus would be reduced considerably, and the loss of aquatic organisms (especially embryonic fishes, eggs, and plankton) due to entrainment and impingement should be reduced as well.[17]

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[16] For a discussion of this variation, see Leuthart and Spencer, Fish Resources and Aquatic Habitat Impact Assessment Methodology.

Although the 72 units added along the Ohio River main stem under the base case are assumed to use once-through cooling under this variation, the rise in water temperature that would occur from bank to bank is projected to be important only locally. Water withdrawal, however, could have a serious impact.

Water withdrawal under the once-through cooling case would be drastically increased for the Ohio River main stem from the withdrawal under base case conditions. This increase could have a devastating entrainment-impingement impact on the main stem under 7-day-10-year low flow conditions. With once-through cooling, the reduction in sensitive species that would occur as a result of entrainment and impingement would range from a maximum of 16.2 percent at Ohio River mile point 70 to 7.53 percent below mile point 772.

The temperature impacts under the once-through cooling case would be damaging locally, especially to sensitive bank habitats. Such temperature impacts would be nonexistent under the base case. With a temperature of 83 degrees Fahrenheit, dissolved oxygen sags would occur from mile point 5.2 to mile point 84.2, with levels reaching less than 4 milligrams per liter at the midpoint. Dissolved oxygen sags would not be significant below mile point 84.2.

7.4 Employment

POWER PLANTS. Between 1975 and 1995 under the base case, a rise in employment of about 327,000 person-years would occur because of power plant construction and operation in the ORBES region.[18] Moreover, the rate of increase in the demand for construction workers would be relatively stable between 1975 and 1995, and thus the potential for short-term labor shortages would be minimal.

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[17] Entrainment is the process by which small organisms, particularly embryonic fish, are caught up in the water intake, are passed through the plant's system, and are killed or severely injured in the process. Impingement is the process by which larger organisms are caught up in the intake current, are trapped on the screen of the intake structure, and are subsequently pounded to death.

[18] Because of the scheduling of power plant construction, these requirements were calculated only through 1995 for all ORBES scenarios considered. For a discussion of such scheduling, see Gary L. Fowler et al., The Ohio River Basin Energy Facility Siting Model (2 vols.). A person-year is

The supply also should be adequate for the three critical skill categories required for power plant construction: boilermakers, electricians, and pipefitters.[19] In 1990, the peak construction year, about 2400 boilermakers, 2300 electricians, and 2600 pipefitters would be needed. It should be noted, however, that such regional projections do not mean that localized shortages would be eliminated.

COAL MINING. In 1985 under the base case, coal production for all purposes would increase by 162 million tons per year over 1974 levels (439.7 million tons), and coal-fired electrical generating facilities in the ORBES region are projected to consume 193.1 million tons of coal, compared with 134.9 million in 1974.[20] By 2000, annual coal production under the base case would be 376 million tons more than production in 1974, and the electric power sector is projected to consume 248.3 million tons.

To meet this increased coal demand for all purposes under base case conditions, coal-mining employment would increase dramatically in the 152 ORBES counties that have concentrations in coal-mining activity. In general, the estimated increase in regional coal mining employment between 1970 and 2000 would be between a minimum of 35 percent and a maximum of 222 percent. It also is projected that at least 79 of the 152 ORBES coal-producing counties would experience mining employment growth rates of 200 percent or more and thus that boom-town effects might be felt in these counties. At least 55 additional counties would experience growth rates between 50 and 199 percent.

7.5 Health

Because of the increased demand for coal under the base case, the

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the equivalent of one person working full time for one year. For the calculation of employment impacts, see Steven I. Gordon and Anna S. Graham, Regional Socioeconomic Impacts of Alternative Energy Scenarios for the Ohio River Basin Energy Study Region (ORBES Phase II).

[19] It was assumed that the growth rate in the supply of these three skills within the ORBES region would be similar to the growth rate of the 1970s and that the proportion of these workers employed in power plant construction during the 1970s would remain constant.

[20] For projections and discussions of regional coal demand, see Donald A. Blome, Coal Mine Siting for the Ohio River Basin Energy Study (ORBES Phase II). Coal is measured in short tons.

occupational and public health impacts related to the coal cycle also would increase in 1985 and 2000.[21]

In 1985 under the base case, about a 44 percent increase would be experienced in the 1975 occupational health impacts related to coal extraction for regional electrical generation. In 2000 under the base case, such impacts would increase by approximately 102 percent (see table 7-3 for absolute values).

In the coal-processing step of the coal cycle, health impacts due to disease are difficult to estimate accurately. Thus, only those impacts related to occupational accidents are projected. In 1985 under the base case, an increase of approximately 44 percent would occur in the health impacts related to coal processing for regional electrical generation. In 2000, an increase of approximately 102 percent would occur over the 1975 impacts (see table 7-3 for absolute values).

Whether statistics based on miles traveled or on weight transported are used, accidental injuries related to coal transport for electrical generation in the ORBES region would be about 45 percent lower in 2000 than they were in 1975. However, accidental deaths related to such transport would be about the same in 2000 as they were in 1975 (see table 7-3 for absolute numbers) since railroad injuries are projected to reduce at a greater rate than deaths.

As stated previously, the number of deaths attributable to air quality is a matter of some controversy (see section 4.6 for an extended discussion). Thus, all projections of future health impacts, although based on findings reported in the current literature, could change as new evidence develops. For the base case, projections are made of both particulate-related and sulfate-related deaths, both of which would be reduced because of the improved air quality resulting from SIP compliance.

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[21] See Maurice A. Shapiro and A.A. Sooky, Ohio River Basin Energy Study: Health Aspects, for a discussion of the estimates relating to the health impacts of coal mining, coal processing, and coal transportation. All estimates for the coal-mining and coal-processing impacts under all the scenarios assume a constant health impact rate using 1975 as a base year, constant thermal efficiency and loading factors in the ORBES-region power plants, similar extraction technologies (that is, deep and surface mining), and a similar processing technique or source of fuel. The coal transportation health impacts for all scenarios assume that coal is distributed to subregions in proportion to the generating capacity in the subregion and that power plants will continue to be supplied with coal from the same sources as in 1975.

Table 7-3
Health Impacts Related to Coal Mining, Processing, and Transportation, Base Case, 1985 and 2000

	1985	2000
COAL MINING		
Accidental deaths	53	75
Disabling injuries	3813	5359
Nondisabling injuries	3155	4435
Disease-related deaths	9	12
Disease-related disabilities	408	573
COAL PROCESSING		
Accidental deaths	6	9
Disabling injuries	336	472
Nondisabling injuries	725	1019
COAL TRANSPORTATION		
Vehicle miles traveled		
Deaths	—	12
Injuries	—	26
Weight transported		
Deaths	—	50
Injuries	—	123

The best estimate of the annual deaths in the region because of electrical generation and the resulting sulfate air pollution is 6350 deaths in 1985 and 5150 deaths in 2000. However, these numbers could be as low as zero or as much as three times higher than estimated because of the uncertain nature of the damage functions used in the calculations.[22] These figures represent reductions from the projected 1975 sulfate-related deaths of 17.5 percent in 1985 and of 35 percent in 2000. As a result of this reduced health damage, the mortality rate under the base case would be reduced by 0.6 percent in 1985 and by about 1 percent in 2000. Cumulative sulfate-related deaths between 1975 and 2000 due to ORBES-region electrical generation could total about 163,000 if a rate of 3 deaths is used per 100,000 persons exposed per microgram of sulfates per cubic meter.

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[22] See Shapiro and Sooky, Ohio River Basin Energy Study: Health Aspects, for a fuller discussion of how these estimates were calculated. Upper and lower limits can be found using a rate of 9 and 0 deaths, respectively, per 100,000 persons exposed per microgram of sulfates per cubic meter. A rate of 3 was used to calculate the numbers reported in the text.

The best estimate of the cumulative deaths expected in the ORBES region because of electrical generation and the resulting particulate air pollution is about 1555.

8. Impacts of the Strict Environmental Control Case

In this chapter, differences in impacts stemming from differences between strict and base case environmental control policies in the ORBES region are summarized and discussed. Under the strict environmental control case, the same assumptions were made as under the base case except with regard to environmental regulations. The strict control case calls for the application of more stringent air, land, and water regulations. For details, see chapter 5.

8.1 Air

Between 1976 and 2000 under the strict environmental control case, utility sulfur dioxide emissions and utility-related annual and episodic concentrations would decrease more than they would under the base case. Utility particulate and nitrogen oxide emissions, however, would be about the same under both scenarios. Cumulative capital costs to install coal-fired generating capacity also would be about the same under both scenarios, although cumulative pollution control costs would be significantly higher under the strict control case. Both the price of electricity and the cumulative revenues required from consumers would be slightly higher under the strict control case.[1]

SULFUR DIOXIDE EMISSIONS. Total utility sulfur dioxide emissions in the ORBES region would be about twice as low under the strict environmental control case in both 1985 and 2000 as they would be under the base case in the same years. This reduction would occur because urban state implementation plans (SIPs), which under strict controls would be applied throughout a state, are much stricter than rural SIPs, which would be in force in rural areas under the base case.

Specifically, with strict environmental controls, sulfur dioxide emissions from all generating units in the ORBES region (SIP units, new source performance standards (NSPS) units, and revised new source performance standards (RNSPS) units) would be about 51 percent lower by 1985 and about 41 percent lower by 2000 than under the base case (see figure 8-1a). Sulfur dioxide emissions from SIP units alone also would be lower (56 percent lower by 1985 and 61 percent lower by 2000). However, emissions from these units still would make up the majority (83 percent) of all utility emissions in 1985 and a sizeable portion (45 percent) of all utility emissions in 2000. Moreover, in 2000 under the strict control case, as under the base case, SIP units would account for only 24 percent of the regional electrical generation. However, since emissions from SIP units would constitute 67 percent of all utility emissions in 2000 under the base case, the strict control case would lead to a more balanced emission-generation ratio.

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[1] No references to other ORBES reports consulted for this chapter are given here or in the succeeding chapters on the coal-dominated futures. These references appear in the corresponding sections of chapter 7.

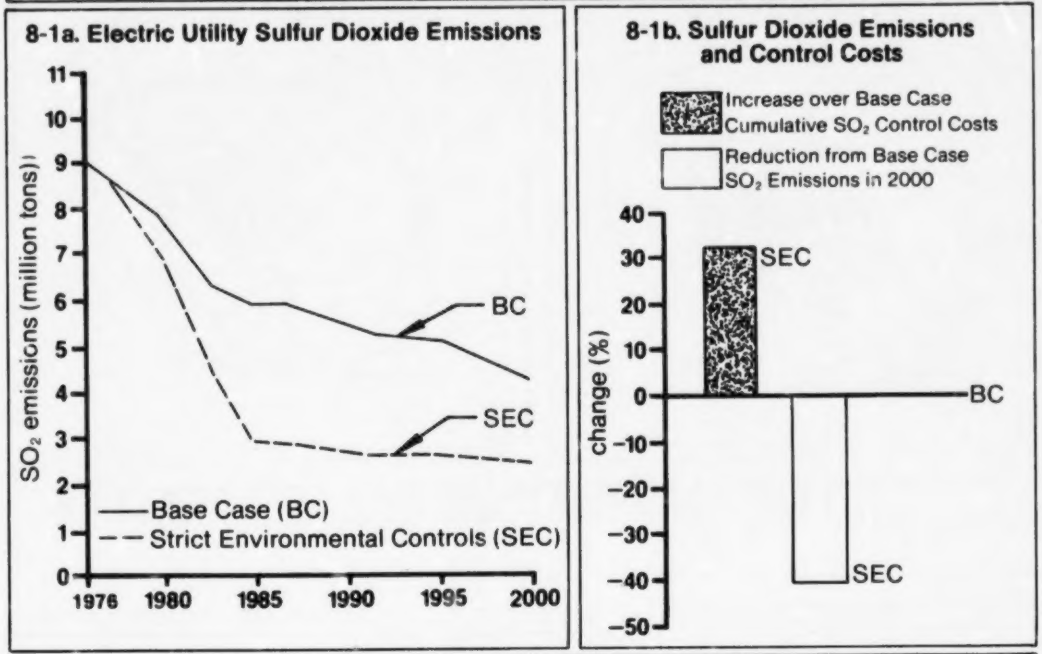
PARTICULATE EMISSIONS. Utility particulate emissions in the ORBES region would be identical in 1985 and nearly the same in 2000 under the strict environmental control case and the base case since SIP particulate standards are assumed to be the same under both cases in both rural and urban areas.

NITROGEN OXIDE EMISSIONS. Utility emissions of oxides of nitrogen in the ORBES region would be almost identical in 1985 and 2000 (less than 1 percent difference) under both the strict environmental control case and the base case. The primary reason for this similarity is that both of these scenarios have the same generating capacity and assume the same nitrogen oxide controls.

SULFUR DIOXIDE AND SULFATE CONCENTRATIONS. If the same conditions of extremely persistent winds were to occur under the strict environmental control case as those that occurred during the August 27, 1974, sulfate episode, the sulfur dioxide and sulfate concentrations related to utility emissions would be so much lower than the concentrations that occurred on August 27, 1974, that they no longer would be considered episodic. Specifically, in the area that experienced the highest episodic concentrations under the base case in 1985, the sulfur dioxide and sulfate concentrations would be 54 and 68 percent lower, respectively, in the same year under the strict control case. In the year 2000, episodic sulfur dioxide and sulfate concentrations would be 50 and 55 percent lower, respectively, under strict controls than under the base case.

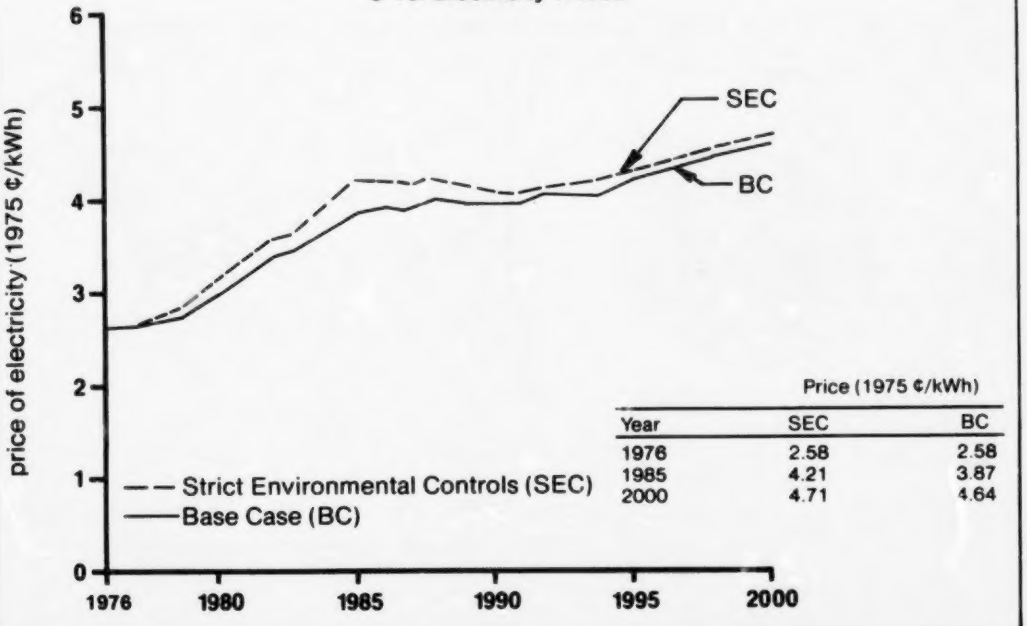
Annual regional sulfur dioxide and sulfate concentrations due to utility sulfur dioxide emissions would be substantially lower under the strict environmental control case than under the base case. In the area that experienced the highest annual concentrations under the base case, sulfur dioxide and sulfate annual concentrations would be significantly reduced both in 1985 (by 46 and 39 percent, respectively) and in 2000 (by 42 and 33 percent, respectively). In figures 8-2 and 8-3, the concentrations that would result in 2000 under the two scenarios are compared. These figures reemphasize that the location of the highest concentrations would tend to stay

Figure 8-1
Base Case versus Strict Environmental Control Case


8-1a. Electric Utility Sulfur Dioxide Emissions

8-1b. Sulfur Dioxide Emissions and Control Costs

8-1c. Electricity Prices



	Price (1975 ¢/kWh)	
Year	SEC	BC
1976	2.58	2.58
1985	4.21	3.87
2000	4.71	4.64

Figure 8-2
Annual Average Sulfur Dioxide Concentrations, Electric Utility Contribution

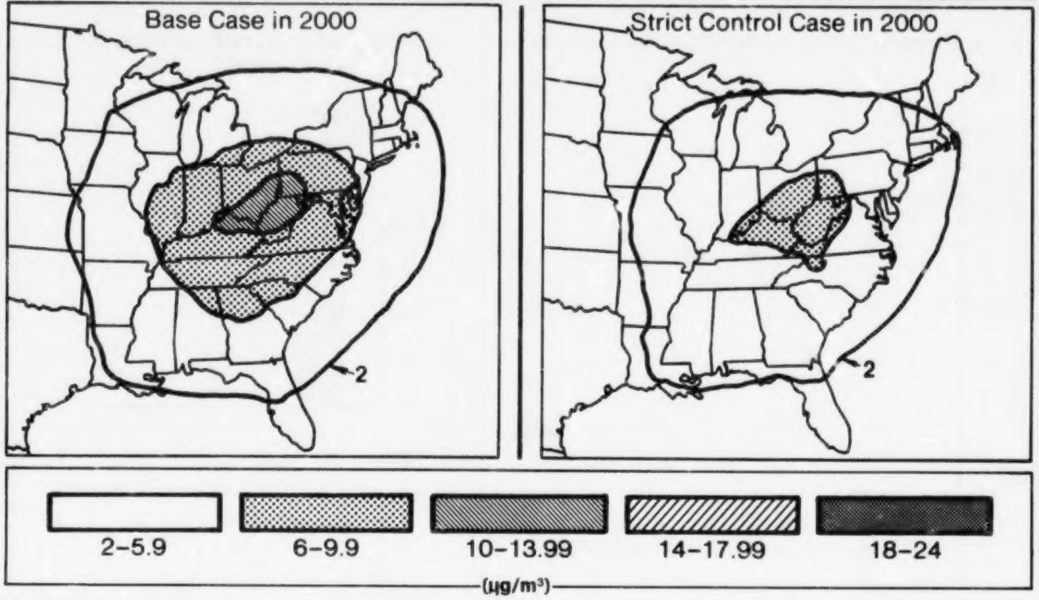
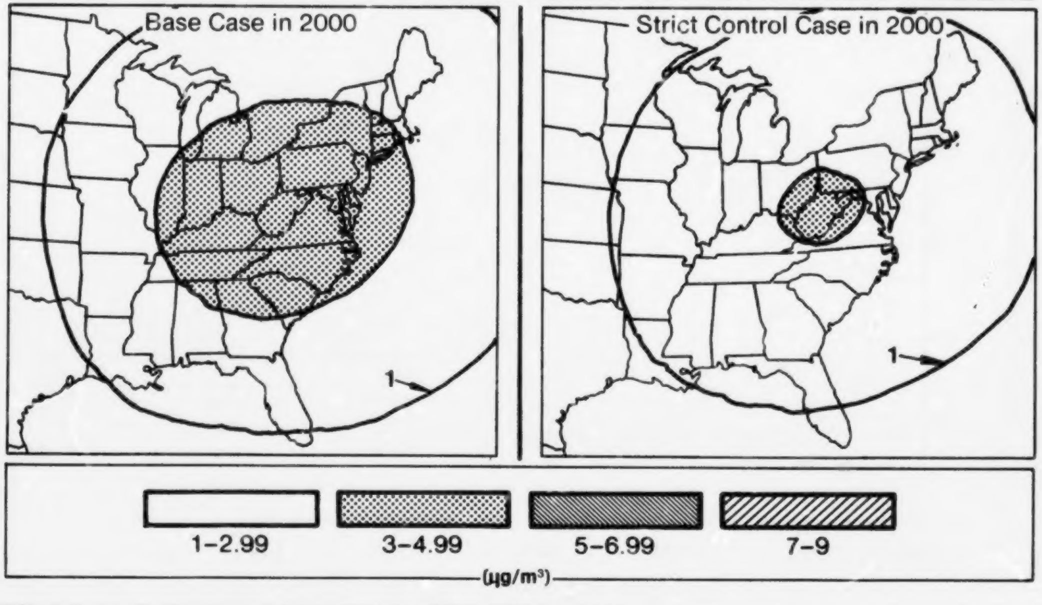

Base Case in 2000
Strict Control Case in 2000
2
2
2-5.9
6-9.9
10-13.99
14-17.99
18-24
(μg/m³)

Figure 8-3
Annual Average Sulfate Concentrations, Electric Utility Contribution


Base Case in 2000
Strict Control Case in 2000
1
1
1-2.99
3-4.99
5-6.99
7-9
(μg/m³)

about the same as under the base case even though the concentrations would be reduced under the strict control case.

UTILITY COSTS. To achieve the air quality regulations of the strict control case, cumulative capital costs for pollution control through the year 2000 would be about 20.7 percent higher than under the base case. This increase would be due entirely to differences in the costs of retrofitting additional SIP units with flue gas desulfurization systems ("scrubbers"); this additional retrofitting would result in costs 32.1 percent higher under the strict control case than under the base case. Thus, a tradeoff is indicated between the emission reductions that could be achieved by the year 2000 and the utility costs to achieve such reductions (see figure 8-1b). The cost of controlling particulate emissions would be nearly identical under both scenarios.

CONSUMER COSTS. Despite the higher capital costs for pollution control under the strict environmental control case, the cost of electricity to the consumer would be only slightly higher (see figure 8-1c). In 1985 under the strict control case, the cost of electricity to the consumer would be 8.8 percent higher than under the base case, primarily because of the costs of retrofitting more SIP units to meet the stricter standards. As the costs are such retrofitting are paid off, however, the cost of electricity under the strict control case would start to level off and would be only 1.5 percent higher in the year 2000 than under the base case. The cumulative revenues collected from consumers between 1976 and 2000 also reflect the similarities between these two scenarios. These cumulative revenues would be only 4 percent higher under the strict control case than under the base case.

8.2 Land

The land conversion required in the ORBES region for all energy-related uses and for electrical generating facilities in particular would be only slightly higher under the strict environmental control case than under the base case. The acreage required for surface mining, however, would be slightly lower under the strict control case. The number of terrestrial ecosystem units assessed would be slightly higher under the strict control case.

LAND USE. Under the strict environmental control case, the land conversion required for all new energy-related uses (new generating facilities, new cooling reservoirs, new transmission line rights-of-way, and new utility surface mining) would be approximately 1 percent higher in 2000 than under the base case. The land required for electrical generating facilities alone would be 1.8 percent higher in 2000. Most of this increase can be attributed to the fact that approximately 40 standard 650 megawatt electrical generating units would be sited in more dispersed locations under the strict control case than under the base case.[2]

The strict environmental control case would result in 5.5 percent more agricultural land being converted for generating facilities than the conversion required under the base case. Most of the additional agricultural land would be converted in the ORBES state portion of Ohio, where more of the dispersed siting occurs. The amount of public land used for electrical generating facilities, however, would be 6.7 percent lower; the amount of forest land, 1.1 percent lower; and the amount of other land, 6.4 percent lower.

In the year 2000 under strict controls, the total regional acreage needed for the surface mining of coal for regional utilities would be less than the acreage needed under the base case. Specifically, 1.2 percent less acreage would be affected by surface mining for utility coal between 1976 and 2000. As a result, the amount of land required at the state level for the surface mining of utility coal would be less than under the base case; the largest decrease (6 percent) would be in the ORBES portion of Illinois.

TERRESTRIAL ECOSYSTEMS. In the ORBES region under the strict control case, the number of terrestrial ecosystem units assessed for the period 1976 to 2000 would be 3 percent higher than the number assessed under the base case between those same years. This difference suggests that counties located inland from the Ohio River corridor generally would have higher ecological assessments (as defined in the model) than counties bordering the river. Only the ORBES portion of Ohio would have fewer terrestrial ecosystem units assessed in 2000 under the strict control case than it would under the base case. In all other ORBES state portions, however, the terrestrial ecosystem units assessed under the strict control case would be slightly higher than those assessed under the base case, ranging from a 1 percent increase in Kentucky to a 9 percent increase in Illinois.

8.2.1 Land Variations

Two variations in land use under the strict control case also were examined; both concern agricultural land protection. In these two variations, the same assumptions and environmental controls as under strict controls prevail except for the fact that a county is excluded as a generating unit site if 50 percent or more of its area is in Class I and II soils. The first variation calls for both agricultural land protection and dispersed siting of electrical generating facilities, while the second calls for such protection and concentrated siting.

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[2] Of these 40 units, 15 are sited in areas of Ohio that are removed from major water sources. If an average-size cooling reservoir (975 acres) were to be built for each of these 15 units, 14,600 more acres would be required under the strict control case than indicated in the text.

The land conversion required for electrical generating facilities under both variations would be lower than that required under the strict control case, although installed capacity would be the same under all three cases (see table 8-1). In general, fewer units are sited in northern Illinois and Indiana and in western Ohio under the dispersed variation. The new units instead are sited in the coal-producing areas of southern Illinois and Indiana and in southeastern Ohio. In the concentrated siting variation, generating units are sited nearer the Ohio River main stem.

Such agricultural land protection policies would help preserve agricultural land, but there would be a corresponding increase in the conversion of forest land. Of the concentrated and dispersed patterns, concentrated siting would require more agricultural land than dispersed siting would; the dispersed pattern would require more forest land (see table 8-2).

Regionwide terrestrial ecosystem units, however, would be only slightly higher under the dispersed siting variation than under the strict control

Table 8-1
Land Converted for Electrical Generating Facilities

	ORBES State Portion						
Scenario	Illinois	Indiana	Kentucky	Ohio	Pennsylvania	West Virginia	ORBES Region Total
				(acres)			
Strict Environmental Controls	30,717	40,643	36,431	31,543	27,990	19,805	187,129
Dispersed Siting, Agricultural Protection	28,562	38,942	32,774	17,159	27,991	33,060	178,488
Concentrated Siting, Agricultural Protection	28,566	38,945	32,777	27,077	27,936	24,228	179,529

Table 8-2
Agricultural and Forest Land Converted for Electrical Generating Facilities

	ORBES State Portion						
Scenario	Illinois	Indiana	Kentucky	Ohio	Pennsylvania	West Virginia	ORBES Region Total
				(acres)			
Strict Environmental Controls							
Agricultural Lands	24,691	26,534	21,165	18,274	6,779	3,790	101,233
Forest Lands	3,353	10,087	12,663	9,601	16,280	14,608	66,592
Dispersed Siting, Agricultural Protection							
Agricultural Lands	21,953	25,416	16,076	7,057	6,911	6,453	83,866
Forest Lands	4,070	10,381	13,987	7,572	15,795	24,586	76,391
Concentrated Siting, Agricultural Protection							
Agricultural Lands	21,328	26,046	17,127	11,841	7,819	5,263	89,424
Forest Lands	4,609	10,217	12,287	11,677	15,199	17,813	71,802

case, while the concentrated siting variation would result in slightly fewer terrestrial units than would the strict case (see table 8-3). The dispersed siting case would result in this higher number of units because the protection of Class I and II soils along with the dispersed criteria would cause a shift to areas with terrestrial ecosystem variables that are more interrelated: forest lands, natural areas, and endangered species.

8.3 Water

The strict environmental control case is unique in several respects with regard to water impacts. It is the only scenario in which electrical generating units (a total of 15) are sited in areas requiring water storage for cooling. It also is one of only two scenarios in which units are sited on relatively small tributaries (the high electrical energy growth case is the other--see section 10.3). However, as under the base case, aquatic habitat impacts under the strict control case and 7-day-10-year low flow conditions would be due largely to the high background levels of pollutants alone or in conjunction with municipal and industrial consumption. Only 2 of the 24

Table 8-3
Terrestrial Ecosystem Assessment Units

	ORBES State Portion						
Scenario	Illinois	Indiana	Kentucky	Ohio	Pennsylvania	West Virginia	ORBES Region Total
Strict Environmental Controls	390	458	268	300	277	164	1857
Dispersed Siting, Agricultural Protection	411	447	274	178	283	273	1866
Concentrated Siting, Agricultural Protection	413	452	241	240	270	191	1807

rivers selected for detailed analysis, the Big Muddy and the Allegheny, would experience impacts related to power plant consumption.

Table 8-4 indicates the differences that would occur under the strict environmental control case during 7-day-10-year low flow conditions from the impacts projected under the base case during these same conditions. As the table indicates, most of the rivers would have the same protection levels and the same aquatic habitat impacts as under the base case. Only five rivers would register changes, and these changes would be in the direction of improvement. It should be noted, however, that most of the water quality indices of the other rivers would change, registering slight improvements over the base case index values. Such improvements suggest that less stress and perhaps fewer violations of water quality parameters would occur on these rivers. Nevertheless, these slight improvements would not be significant enough to change the overall aquatic habitat impacts.

The reason for these improvements in the index--even when units are added to a stream--concerns two assumptions. First, it is assumed that all but 5 percent of power plant effluents will be controlled under the strict control case, while the base case assumes no effluent controls. Moreover, the strict control case also assumes that by the year 2000 background levels will be one-half of the levels that are assumed for the base case, as well as for all other scenarios. As a result, under strict controls, the White River, for example, can have three more units added than under the base case, have a

Table 8-4
Aquatic Habitat Impacts, Base Case versus Strict Environment Control Case, 7-Day–10-Year Low Flow, Year 2000

River	Better (+) Worse (–) Same (0) As Base Case Habitat Impacts	Water Quality Impact Index (range: 0 to 100)	Change in Base Case Protection Levels	Change in Base Case Habitat Impacts	Number of Units Added or Removed from Base Case
Allegheny	0	25			+ 4
Beaver	0	25			– 3
Big Muddy	+	15	B	Moderate	
Big Sandy	0	33			+ 1
Cumberland	0	25			
Great Miami	0	25			+ 1
Green	0	25			
Illinois	+	15	B	Moderate	– 5
Kanawha	0	25			+ 1
Kaskaskia	0	15			
Kentucky	—	—	*	—	
Licking	+	16	B	Moderate	
Little Miami	0	41			+ 1
Mississippi	0	15			
Monongahela	0	25			
Muskingum	0	30			– 3
Ohio Main Stem	0	33			–29
Rock	—	—	*	—	
Salt	—	—		—	
Scioto	0	25			
Susquehanna	—	—	*	—	
Wabash	0	15			+ 2
White	0	15	C	Moderate	+ 3
Whitewater	—	—	*	—	+ 1

*Background data unavailable; analysis could not be completed.

water quality index value of 15 rather than 30, and have moderate rather than heavy aquatic habitat impacts. Similarly, a stream like the Big Sandy, which had no scenario additions or planned capacity under either the base case or the strict control case, still would register improvements in its index (from 39 to 33); both indices, however, indicate heavy aquatic habitat impacts. Thus, as a whole, despite the assumptions concerning loadings and background concentrations, few changes in overall aquatic habitat impacts would be registered under the strict control case. These results suggest that background levels are so high that they would have to be reduced by more than half to avoid serious aquatic habitat impacts under 7-day-10-year low flow conditions.

As under the base case, the Allegheny and the Big Muddy rivers would be the only two rivers whose impacts are related to high background concentrations and power plant consumption rather than to such concentrations alone or in conjunction with municipal and industrial consumption. The Allegheny would experience such impacts because of the large added capacity; the Big Muddy, because it is a very small stream.

Two general observations can be made about the impacts projected to occur under strict controls because of power plant consumption. First, minor shifts in siting patterns or the use of alternative cooling technologies could alleviate power-plant-related water quality problems. Second, even though many of the region's smaller tributaries, such as the Big Muddy, meet criteria for water supply, these streams probably are not suitable for the siting of 650 megawatt electric units under either strict environmental controls or the base case. However, as discussed in chapter 6, such shifts in siting could cause other environmental impacts to occur. Moreover, high background concentrations are the main reason for most of the water quality problems under strict controls--even though these concentrations are assumed to be 50 percent lower. However, as discussed previously, it is improbable that background concentrations can be reduced during the time frame of this study since nonpoint and geochemical sources account for most of these concentrations, and these sources probably will not be brought under control by the year 2000.

8.4 Employment

POWER PLANTS. Under the strict environmental control case, employment related to power plant construction and operation would be about 7 percent higher between 1975 and 1995 than it would be under the base case between those same years. Moreover, as under the base case, the rate of increase in the demand for construction workers would be relatively stable between 1975 and 1995, and thus the potential for short-term labor shortages would be minimal.

The differences in labor demand between these two scenarios would occur primarily because the strict environmental control case assumes the use of scrubbers on both urban and rural electrical generating units. Under the base case, however, scrubbers would be required only on urban units. Labor requirements for the construction of facilities with scrubbers are about 16 percent higher than those for similar facilities without scrubbers.

The strict environmental control case also would employ slightly more (about 5.7 percent more) power plant construction and operation workers in 1990 than would the base case in the three critical skill categories examined--boilermakers, electricians, and pipefitters. In addition, the demand for boilermakers would be high and the possibility of a shortage in this skill category would exist. The demand for electricians and pipefitters should be met easily.

The slightly higher labor demand under the strict control case as compared to the base case is interesting in light of the dispute over the use of scrubbers. Such higher employment benefits, plus the fact that the high-sulfur coals in the ORBES region would be more competitive and keep more miners employed, are a tradeoff with the costs of building such systems.

Because the increased use of scrubbers by electrical generating facilities under the strict control case would result in a decrease in thermal efficiency, generating facilities would have to burn more coal to produce the same amount of electricity as under the base case. To meet the increased needs of these facilities as well as the needs of all other industries, annual coal production would be slightly higher (about 2 percent) by 2000 under the strict control case than under the base case in that year. Similarly, electrical generating units also would consume approximately 2 percent more tons of coal in 2000 under the strict control case than they would under the base case in 2000.

However, since the demand for coal would be similar under the strict control case and the base case, both scenarios would require essentially the same numbers of coal-mining workers for all purposes. For example, regional coal-mining employment would increase between 36 and 231 percent under the strict control case, compared with a range of 35 to 222 percent under the base case. Moreover, differences in coal-mining employment trends, as well as in the geographical distribution of this employment, would be minimal. For example, only 4 more counties might experience boom-town effects under strict controls than might experience such effects under the base case. At least 53 counties would experience growth rates between 50 and 199 percent under the strict control case, compared to at least 55 such counties under the base case.

8.5 Health

Since the demand for coal for electrical generation would be nearly the same under the strict control case as under the base case, and since nearly the same number of workers are needed under both cases, the same health impacts are projected to occur under both cases in the coal-mining, coal-processing, and coal transportation sectors. Similarly, since utility particulate levels would be almost identical under the two scenarios, the number of deaths related to emissions of this pollutant would be almost the same under both scenarios. However, because the regional sulfur dioxide air quality would improve significantly under strict controls, substantially fewer cumulative deaths (about 33 percent fewer) are projected to occur between 1975 and 2000 from sulfate air pollution by ORBES-region electrical generating facilities. This cumulative reduction is projected based on annual average deaths that are 58 percent lower in 1985 and 52 percent lower in 2000 than they would be under the base case in 1985 and 2000, respectively.

9. Impacts of the SIP Noncompliance Case

This chapter sets forth comparisons in impacts between the base case (the SIP compliance case) and the SIP noncompliance case. However, neither employment nor water quality analyses were conducted for the SIP noncompliance case.

The primary assumption of the SIP noncompliance case is that present state implementation plans (SIPs) will not be enforced in the ORBES region. Currently, SIPs exist for sulfur dioxide and particulates in all six of the ORBES states. Only the urban areas of Illinois, however, are regulated by a SIP for oxides of nitrogen. Other than this assumption, the noncompliance case is identical to the base case.

9.1 Air

If state implementation plans are not complied with, regional utility sulfur dioxide and particulate emissions would be substantially higher than those under the base case. As under all of the coal-dominated scenarios, utility emissions of oxides of nitrogen would increase between 1976 and 2000 under the SIP noncompliance case. Regional episodic and annual sulfur dioxide and sulfate concentrations related to utility sulfur dioxide emissions also would increase under SIP noncompliance. However, costs to both utilities and consumers would decrease under the noncompliance case since less pollution control equipment would be installed under the noncompliance case than under the base case.[1]

SULFUR DIOXIDE EMISSIONS. Utility sulfur dioxide emissions in the ORBES region would range from 70 to 120 percent higher between 1985 and 2000 under the SIP noncompliance scenario than under the base case. More specifically, the sulfur dioxide emissions from regional, noncomplying SIP units would be 81 percent higher in 1985 and 121 percent higher in 2000 than the emission levels for SIP units under the base case in those years. Sulfur dioxide emissions from all generating units in the ORBES region (SIP units, new source performance standards (NSPS) units, and revised new source performance standards (RNSPS) units) would be 66 percent higher by 1985 and 74 percent higher by 2000 than base case emission levels for all units in those years (see figure 9-1a). Since SIP emissions would constitute 98 percent of all utility emissions in 1985 and 86 percent in 2000 under the SIP noncompliance scenario, noncompliance would be responsible for almost all of the emission-related impacts projected to occur. However, SIP units would account for only 40 percent of total regional electrical generation in 2000 under the SIP noncompliance case. The disproportionality of the emission-generation ratio thus emphasizes the disadvantages of such noncompliance.

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[1] See the corresponding sections of chapter 7 for references to the other ORBES reports consulted for this chapter.

Plant Lifetime. It is interesting to note the significant emission increases that are projected to occur under the SIP noncompliance case when longer generating unit lifetimes are assumed. In the year 2000, total utility sulfur dioxide emissions would be 7.55 million tons assuming a 35-year generating unit life, 10.1 million tons assuming a 45-year life, and 11.1 million tons assuming a 55-year life. Thus, utility sulfur dioxide emissions would be 25 percent higher in the year 2000 with a 45-year plant life than with a 35-year life, and 32 percent higher in that year with a 55-year life than with a 35-year life.[2]

PARTICULATE EMISSIONS. In both 1985 and 2000, utility particulate emissions in the ORBES region would be as much as six times higher under the SIP noncompliance case than the emissions that would be expected under compliance, or the base case, in those years.

NITROGEN OXIDE EMISSIONS. Utility emissions of oxides of nitrogen in the ORBES region, however, would not be significantly different in either 1985 or 2000 under the SIP noncompliance case and the base case. Similar emission levels would result because none of the ORBES states has SIP standards for nitrogen oxides, except for the urban areas of Illinois. Thus, since both scenarios have the same nitrogen oxide standards and generate about the same amount of electricity, they would result in about the same utility nitrogen oxide emissions.

SULFUR DIOXIDE AND SULFATE CONCENTRATIONS. If the same conditions of extremely persistent winds were to occur under the SIP noncompliance case as those that occurred during the August 27, 1974, sulfate episode, sulfur dioxide and sulfate concentrations due to utility emissions would be much higher. In 1985, in the area that experienced the highest episodic concentrations due to utilities under the base case, sulfur dioxide concentrations would be 71 percent higher; sulfate concentrations would be 42

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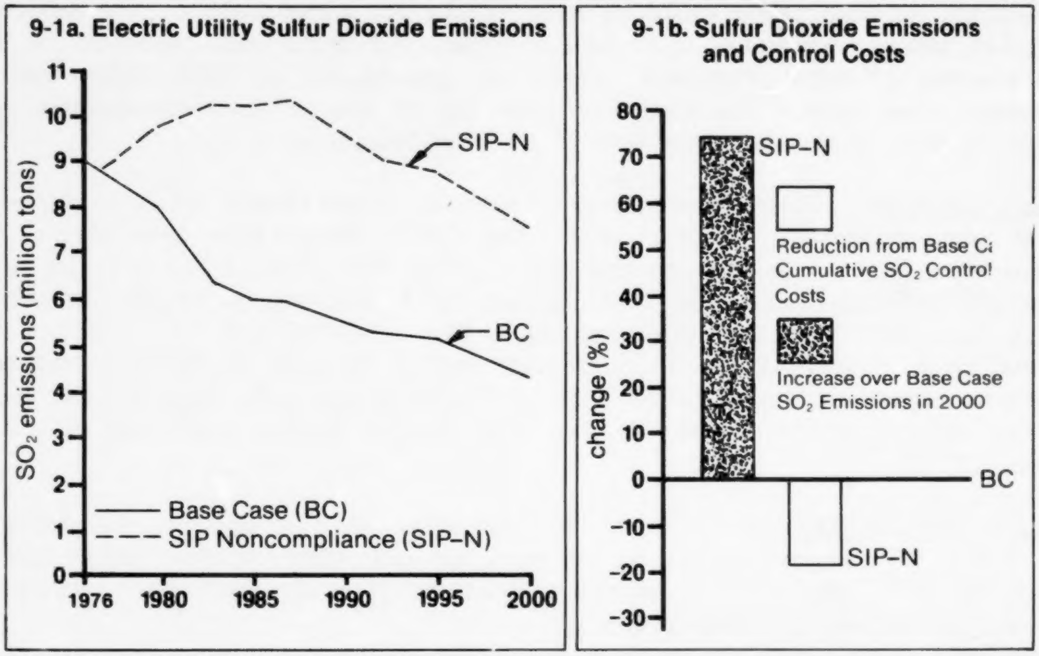
[2] See chapter 6 for the possible effect on plant lifetimes of a change in the regulatory definition of a modification to an existing unit.

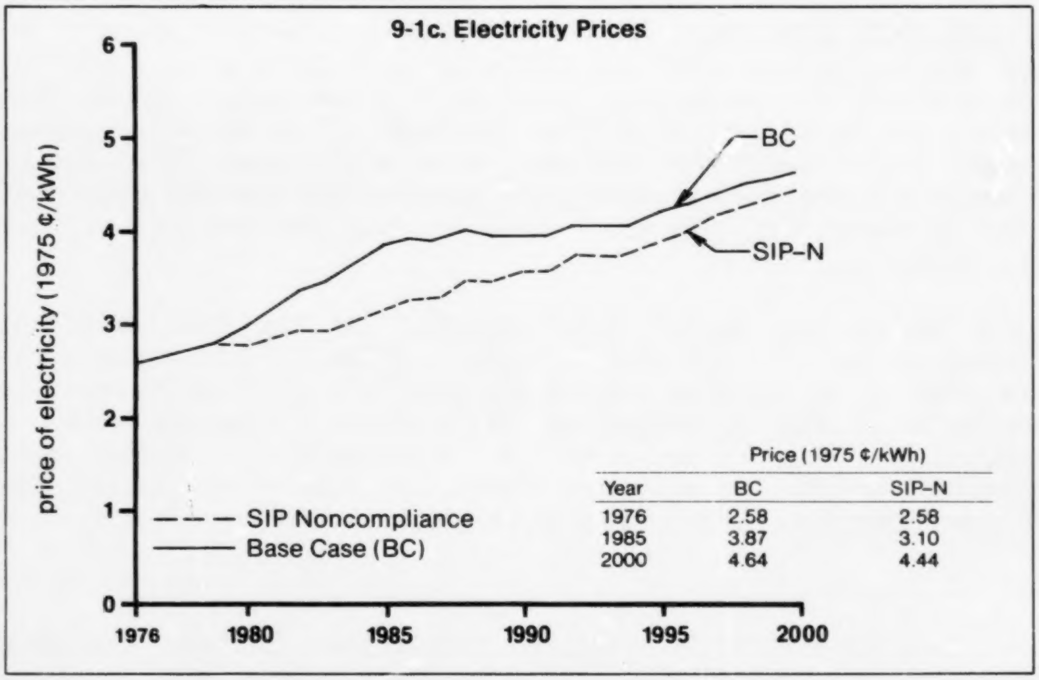
Figure 9-1
Base Case versus SIP Noncompliance Case



9-1a. Electric Utility Sulfur Dioxide Emissions

9-1b. Sulfur Dioxide Emissions and Control Costs

9-1c. Electricity Prices



	Price (1975 ¢/kWh)	
Year	BC	SIP–N
1976	2.58	2.58
1985	3.87	3.10
2000	4.64	4.44

percent higher in that area. By 2000, regional episodic sulfur dioxide and sulfate concentrations in the same area would be 71 and 41.6 percent higher, respectively, than under the base case in that year.

Annual concentrations in the ORBES region due to utility sulfur dioxide emissions would be substantially higher under the SIP noncompliance case than under the base case. In 1985, in the area that experienced the highest annual concentrations under the base case, annual sulfur dioxide and sulfate concentrations would be about 61 and 54 percent higher, respectively, than the concentrations projected under the base case for that year. In 2000 under SIP noncompliance, annual sulfur dioxide and sulfate concentrations in the same area would be about 64 and 56 percent higher, respectively, than the concentrations projected under the base case for that year. Figures 9-2 and 9-3 emphasize the differences between these two scenarios in annual average concentrations within the region in the year 2000.

UTILITY COSTS. With SIP noncompliance, cumulative costs for pollution control through the year 2000 would be about 30 percent lower than under the base case. The cost of controlling sulfur dioxide emissions would be about 18 percent lower under the noncompliance case than the cost under the base case since no SIP units would be retrofitted with sulfur dioxide control systems under the noncompliance case. However, this 18 percent difference in sulfur dioxide pollution control costs translates into a 74 percent increase in utility sulfur dioxide emissions by the year 2000 (see figure 9-1b). Because of noncompliance with SIP particulate limits, the cost of controlling particulate emissions would be about 54 percent lower than under the base case. As a result of the lower pollution control costs under the SIP noncompliance case, cumulative costs to the utilities between 1976 and 2000 for new coal-fired generating capacity and for retrofitting and installing pollution control devices would be about 5 percent lower under the SIP noncompliance case than such costs would be under the base case.

CONSUMER COSTS. With these reduced pollution control costs, the cost of electricity to the consumer would be about 20 percent lower in 1985 under the SIP noncompliance case than under the base case in that year. By 2000, however, the price of electricity would be only about 4 percent lower under the noncompliance case than it would be under the base case (see figure 9-1c). The reason why there is such a small difference between the two scenarios in 2000 concerns the fact that the compelling forces behind rising prices between 1985 and 2000 would be the expansion and replacement of generating capacity. The cumulative revenues required from consumers between 1976 and 2000 would be about 9 percent lower under the SIP noncompliance case than under the base case ($475 billion under the former case and $525 billion under the latter).

9.2 Land

Since the generating capacity and the siting would be the same under both

Figure 9-2
Annual Average Sulfur Dioxide Concentrations, Electric Utility Contribution

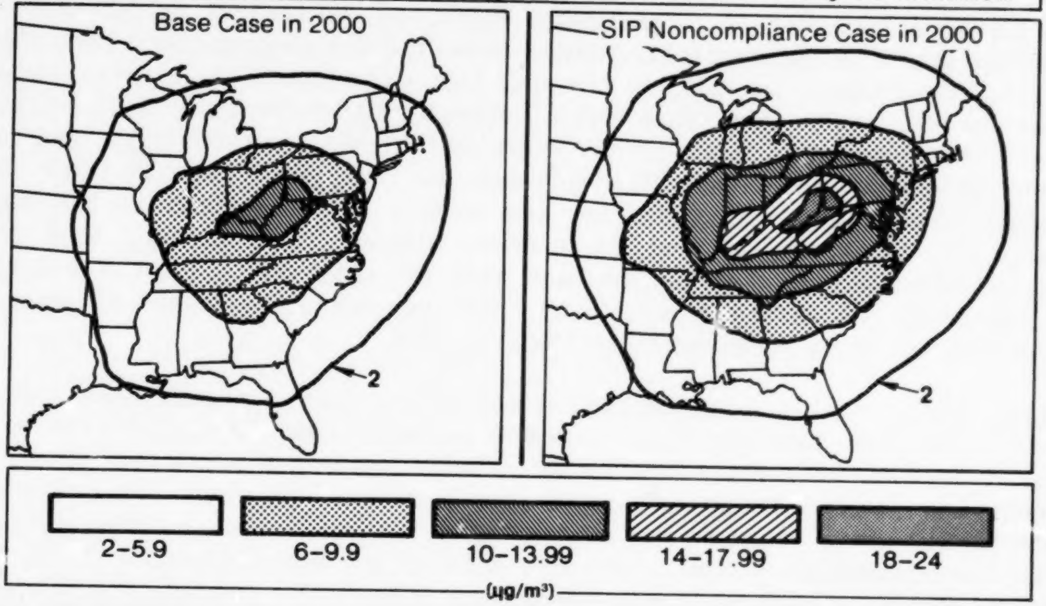
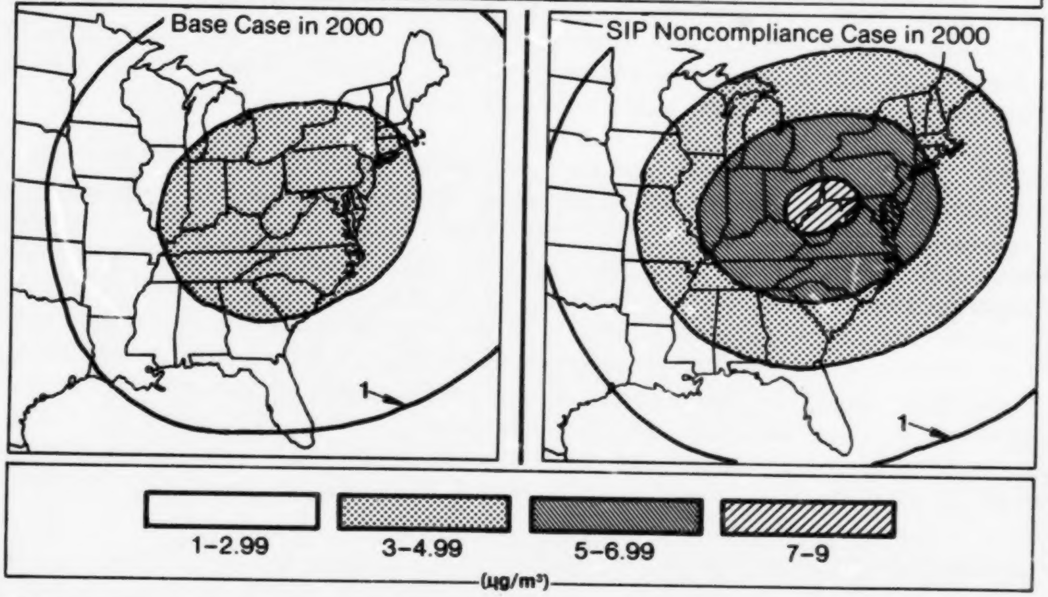

Base Case in 2000
SIP Noncompliance Case in 2000
2
2
2–5.9
6–9.9
10–13.99
14–17.99
18–24
(μg/m³)

Figure 9-3
Annual Average Sulfate Concentrations, Electric Utility Contribution


Base Case in 2000
SIP Noncompliance Case in 2000
1
1
1–2.99
3–4.99
5–6.99
7–9
(μg/m³)

the base case and the SIP noncompliance case, the amount of land converted and the number of terrestrial ecosystem units assessed also would be the same under both scenarios. However, because utility sulfur dioxide emissions would be significantly higher under the noncompliance case, related regional crop losses also are estimated to be higher. On the other hand, because utility and thus total nitrogen oxide emissions under SIP noncompliance would change little from the emissions projected under the base case, crop losses due to oxidants formed from such emissions as well as forest losses (which are due primarily to ozone) are estimated to be the same under both scenarios in both 1985 and 2000. Thus, any change in crop losses under the noncompliance case would be related to sulfur dioxide emissions. Since losses due to ozone impacts account for about 98 percent of regional crop losses, any change in the sulfur-dioxide-related losses would be a small percentage of the total losses.

In general under SIP noncompliance, substantially more acres than under the base case would be affected by utility-related sulfur dioxide concentrations of 130 micrograms per cubic meter in the presence of moderate ozone levels (0.06 to 0.1 parts per million). Under SIP noncompliance, 114 and 105 percent more land would be affected in 1985 and 2000, respectively, by such concentrations than would be affected under the base case in those years. Thus, while under the base case the land affected by such concentrations would represent 4.8 percent of the ORBES region in 1985 and 3.1 percent in 2000, such concentrations under SIP noncompliance would affect 9.6 percent of the region in 1985 and 6.2 percent in 2000.

PHYSICAL CROP LOSSES. Regional agricultural losses due to such sulfur dioxide concentrations are estimated to be substantially greater under SIP noncompliance than the losses projected under the base (SIP compliance) case. In 1985 under SIP noncompliance, regional soybean, wheat, and corn losses would result in a combined loss ranging from a minimum of 817,000 bushels to a maximum of 5.6 million bushels; the probable combined loss is estimated to be 3 million bushels. These ranges are about 140 percent higher than the ranges estimated under the base case in 1985. In the year 2000, the combined loss under the SIP noncompliance case would range from a minimum of 564,000 bushels to a maximum of 4 million bushels, with 2.2 million bushels representing the probable loss. These ranges are about 136 percent higher than the ranges estimated under the base case in 2000.

Under the SIP noncompliance case, as under the base case, agricultural losses related to sulfur dioxide would represent less than 1 percent of the total regional yield. However, on a local scale, such as the county, losses could be significant; losses to individual farmers could be substantial. For example, as under the base case, the ORBES state portion of Illinois would account for most of the regional crop losses--from 45 to 56 percent of the regional losses in 1985 and from 54 to 68 percent in 2000, depending on the crop. Illinois together with two other ORBES state portions--Indiana and

Ohio--would account for about 95 percent of these estimated sulfur dioxide losses.

MONETARY CROP LOSSES. The cumulative regional agricultural dollar losses--comprising wheat, corn, and soybean losses--would be almost identical under both the SIP noncompliance case and the SIP compliance (base) case for losses associated with utility sulfur dioxide concentrations and with ozone concentrations due to regional nitrogen oxide emissions. Furthermore, the distribution of monetary losses across the ORBES state portions would be almost identical under both scenarios. Thus, agricultural dollar losses, as well as the distribution of these losses, are not at all sensitive to alternative policy statements concerning SIP compliance.

9.3 Health

Since coal-fired installed capacity would be the same in 1985 and in 2000 under both the base case and the SIP noncompliance case, health impacts in the coal-mining and coal-processing sectors would be the same under both cases.

However, because air quality would be significantly worse under SIP noncompliance, substantially more cumulative deaths are projected to occur between 1975 and 2000 from sulfate and particulate air pollution by electrical generating facilities in the ORBES region. Under SIP noncompliance, cumulative deaths related to sulfate air pollution are estimated to be 34 percent higher than under the base case. The annual number of deaths associated with sulfate air pollution would be 55 percent higher in 1985 and 62 percent higher in 2000 than they would be under the base case in those years. Cumulative deaths related to particulate air pollution are projected to be 162 percent higher under the SIP noncompliance case than under the base case.

10. Impacts of the High Electrical Energy Growth Case

In this chapter, the effects of high electrical energy growth in the ORBES region (at an annual average rate of 3.9 percent between 1974 and 2000) are compared with those of energy growth under the base case (3.13 percent annually). The high electrical energy growth case also assumes a 45-year lifetime for new generating units, while the base case assumes a 35-year lifetime for new units. As a result of the high electrical energy growth projected, installed generating capacity in the ORBES region would be 178,372 megawatts electric in the year 2000, compared with 153,245 megawatts electric under the base case. Other than the electrical energy growth and generating unit lifetime assumptions, the base case and the high electrical energy growth case are the same. For more details, see chapter 5.

Two variations of the main high growth scenario also were examined in the air quality analyses; these variations are discussed in section 10.1.1.

10.1 Air

The high electrical energy growth case and the base case would result in about the same utility sulfur dioxide, particulate, and nitrogen oxide emissions and about the same regional sulfur dioxide and sulfate concentrations in 1985. These emissions and concentrations would be similar in 1985 because the same generating capacity is assumed for both scenarios in that year. However, since capacity expands more under the high growth case after 1985, and since generating units have a 45-year rather than a 35-year lifetime, all emissions and concentrations would be higher under the high growth case than under the base case by the year 2000.[1]

EMISSIONS. Under high electrical energy growth, sulfur dioxide emissions from units regulated by state implementation plans (SIPs) would be 47 percent greater in 2000 than the emissions from SIP-regulated units under the base case in that year. SIP emissions also would make up 71 percent of the regional utility emissions in 2000 under the high growth case, although units regulated by SIPs would account for only 25 percent of the total regional electrical generation in 2000. Additional data suggest that the majority of the increase in emissions would be attributable to the differences in plant lifetimes and not to the differences in electrical energy growth. Utility sulfur dioxide emissions from all units would be 39 percent higher in 2000 under high electrical growth than under the base case (see figure 10-1a). By 2000 under the high electrical energy growth case, utility particulate emissions would be 36.8 percent higher than base case levels in that year. Similarly, utility nitrogen oxide emissions would be 31.5 percent higher in 2000 than they would the be under the base case in that year.

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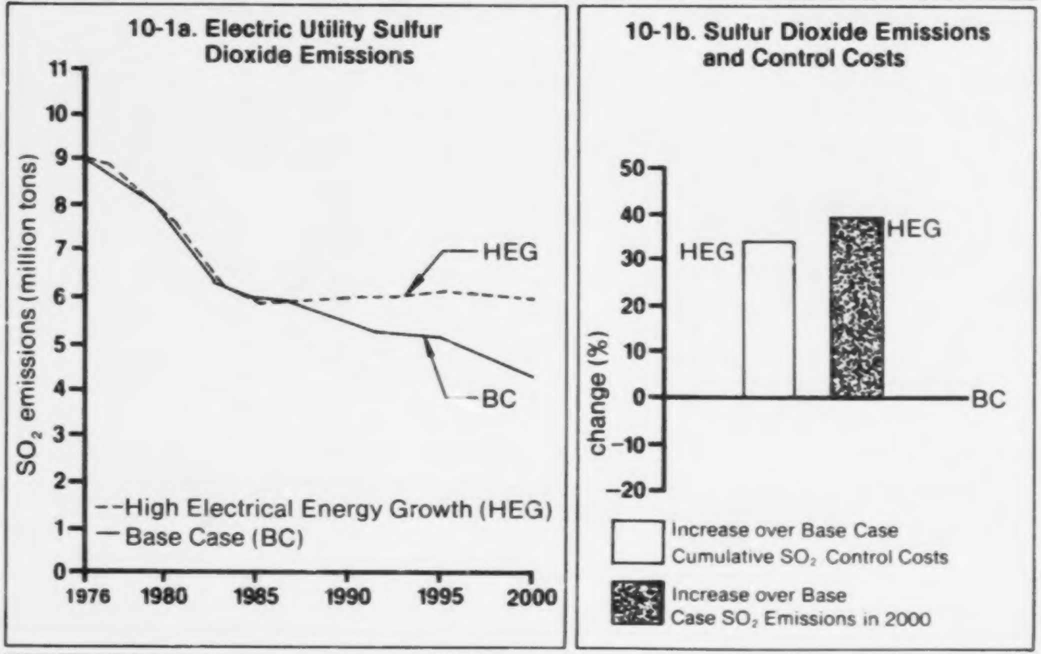
[1] References to the other ORBES reports consulted for this chapter appear in the corresponding sections of chapter 7.

CONCENTRATIONS. If the same conditions of extremely persistent winds were to occur under the high growth case in 2000 as those that occurred during the August 27, 1974, sulfate episode, utility-related sulfur dioxide and sulfate concentrations would be higher than under base case conditions in 2000. In the area of highest concentrations under the base case, for example, utility-related sulfur dioxide and sulfate concentrations would be about 37 and 65 percent higher, respectively, under the high growth case.

In the year 2000, annual regional sulfur dioxide and sulfate concentrations due to utility sulfur dioxide emissions would be about 43 and 47 percent higher, respectively, under the high electrical energy growth case in the area of highest concentration than the projected concentrations in the same area under the base case. Figures 10-2 and 10-3 illustrate the differences between the annual concentrations under the base case and under the high growth case. Figure 10-2 compares annual sulfur dioxide concentrations in the year 2000 under both scenarios. As this figure indicates, the area along the Ohio River main stem still would be the most affected portion of the ORBES region under high growth, although more of that area would be affected by higher concentrations. Figure 10-3 compares annual sulfate concentrations under the two scenarios. As shown by the figure, the acreage affected by the highest concentration--almost the entire ORBES region--would be almost identical under both scenarios; the concentration levels, however, would increase under the high growth case.

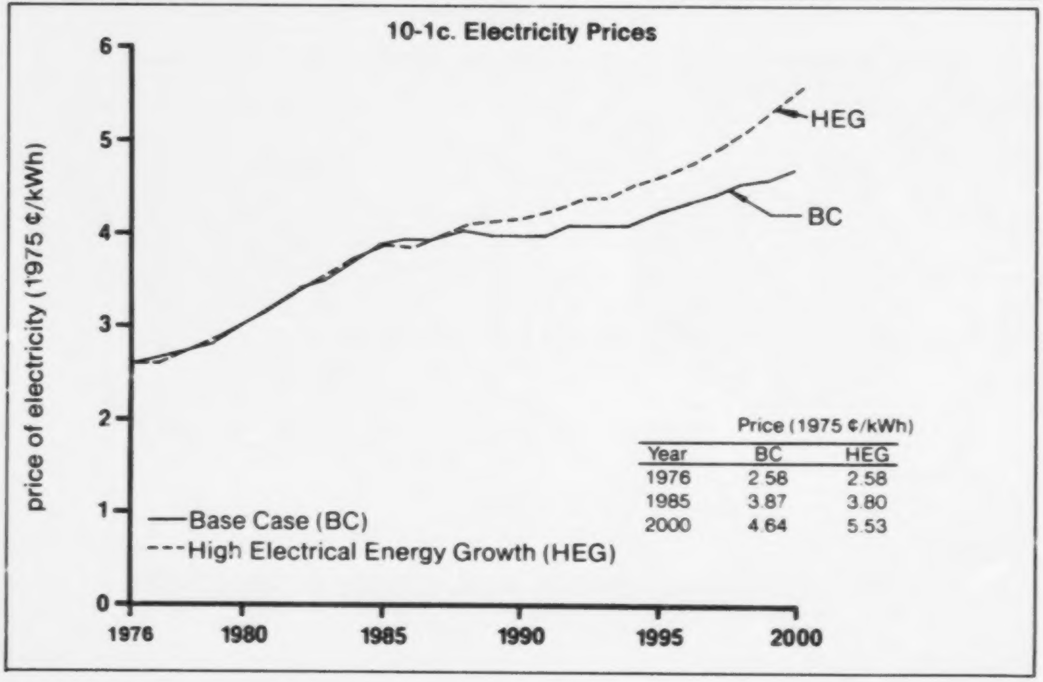
UTILITY COSTS. Cumulative capital costs for new coal-fired generating capacity in the ORBES region, exclusive of pollution control costs, would be substantially higher (35 percent higher) under the high electrical energy growth case than they would be under the base case. Pollution control costs would be similarly higher under the former case: sulfur dioxide pollution control costs would be about 34 percent higher than under the base case, and particulate emission control costs would be about 15 percent higher. These higher pollution control costs are entirely the result of the increased generating capacity under the high growth case. Thus, both the high electrical energy growth case and the base case would result in pollution control costs that are about 21 percent of the total cumulative costs for achieving the installed capacity and the environmental regulations under both

Figure 10-1
Base Case versus High Electrical Energy Growth Case (45-Year Plant Life)



10-1a. Electric Utility Sulfur Dioxide Emissions

10-1b. Sulfur Dioxide Emissions and Control Costs



10-1c. Electricity Prices

	Price (1975 ¢/kWh)	
Year	BC	HEG
1976	2.58	2.58
1985	3.87	3.80
2000	4.64	5.53

Figure 10-2
Annual Average Sulfur Dioxide Concentrations, Electric Utility Contribution

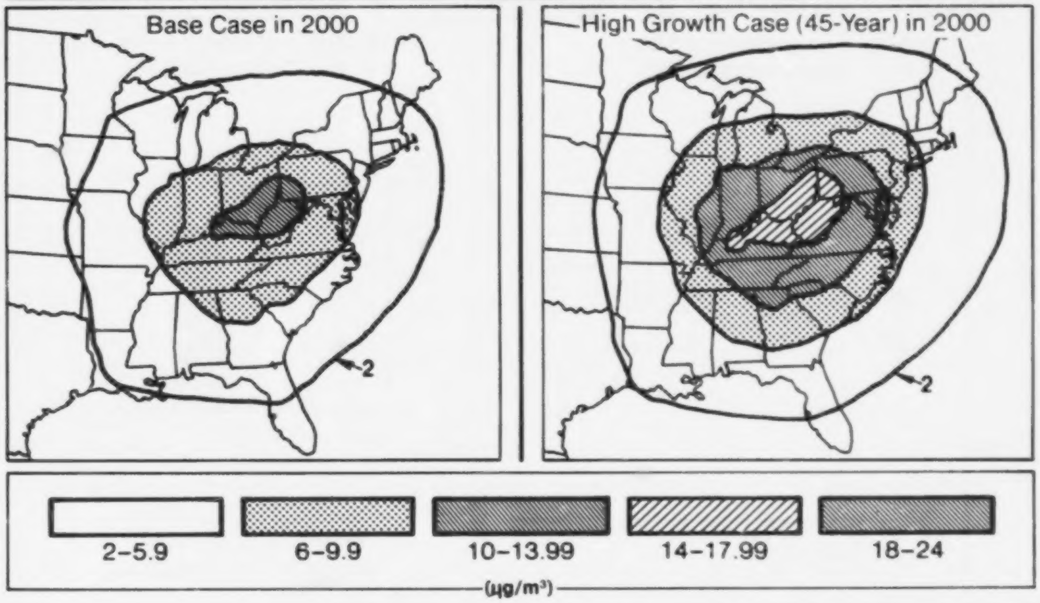
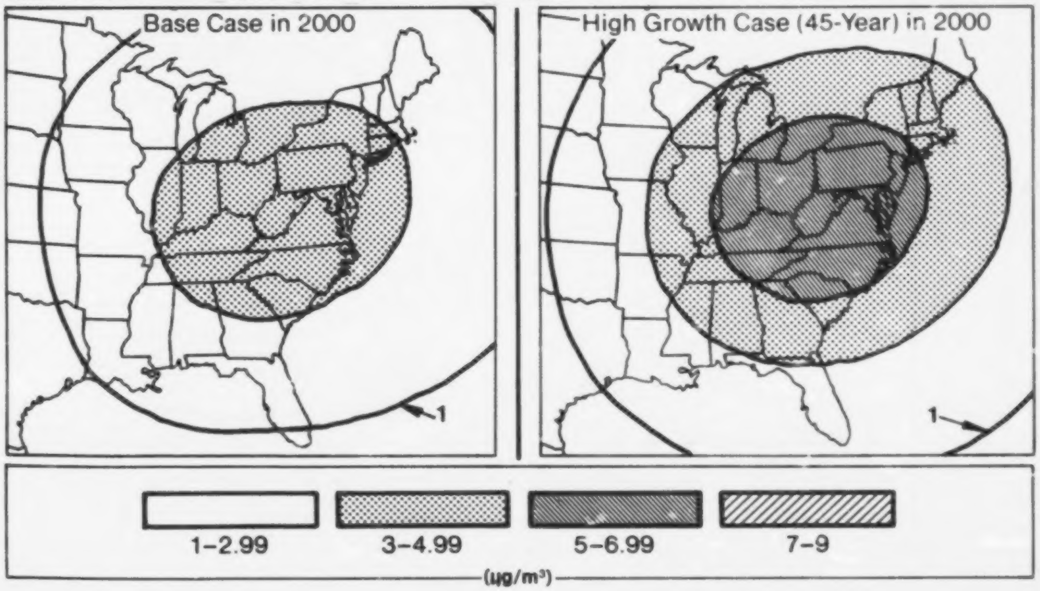

Base Case in 2000
High Growth Case (45-Year) in 2000
2
2
2–5.9
6–9.9
10–13.99
14–17.99
18–24
(μg/m³)

Figure 10-3
Annual Average Sulfate Concentrations, Electric Utility Contribution


Base Case in 2000
High Growth Case (45-Year) in 2000
1
1
1–2.99
3–4.99
5–6.99
7–9
(μg/m³)

scenarios. Moreover, the increase in sulfur dioxide pollution control costs in comparison to the increase in sulfur dioxide emissions under the high growth case suggests that such pollution control costs merely parallel generating capacity (see figure 10-1b).

CONSUMER COSTS. Since both the base case and the high electrical energy growth case have the same installed generating capacity in 1985, the price of electricity would be nearly the same in that year under both scenarios. However, because of the growth in electricity demand that would occur after 1985 under the high growth case, electricity prices would be significantly higher in 2000 (19 percent) under this case than under the base case in that year (see figure 10-1c). This increase between 1985 and 2000 also is reflected in the cumulative revenues collected from consumers between 1976 and 2000. Such revenues would be about 18 percent higher under the high growth case than under the base case, or $617 billion under the former case and $525 billion under the latter.

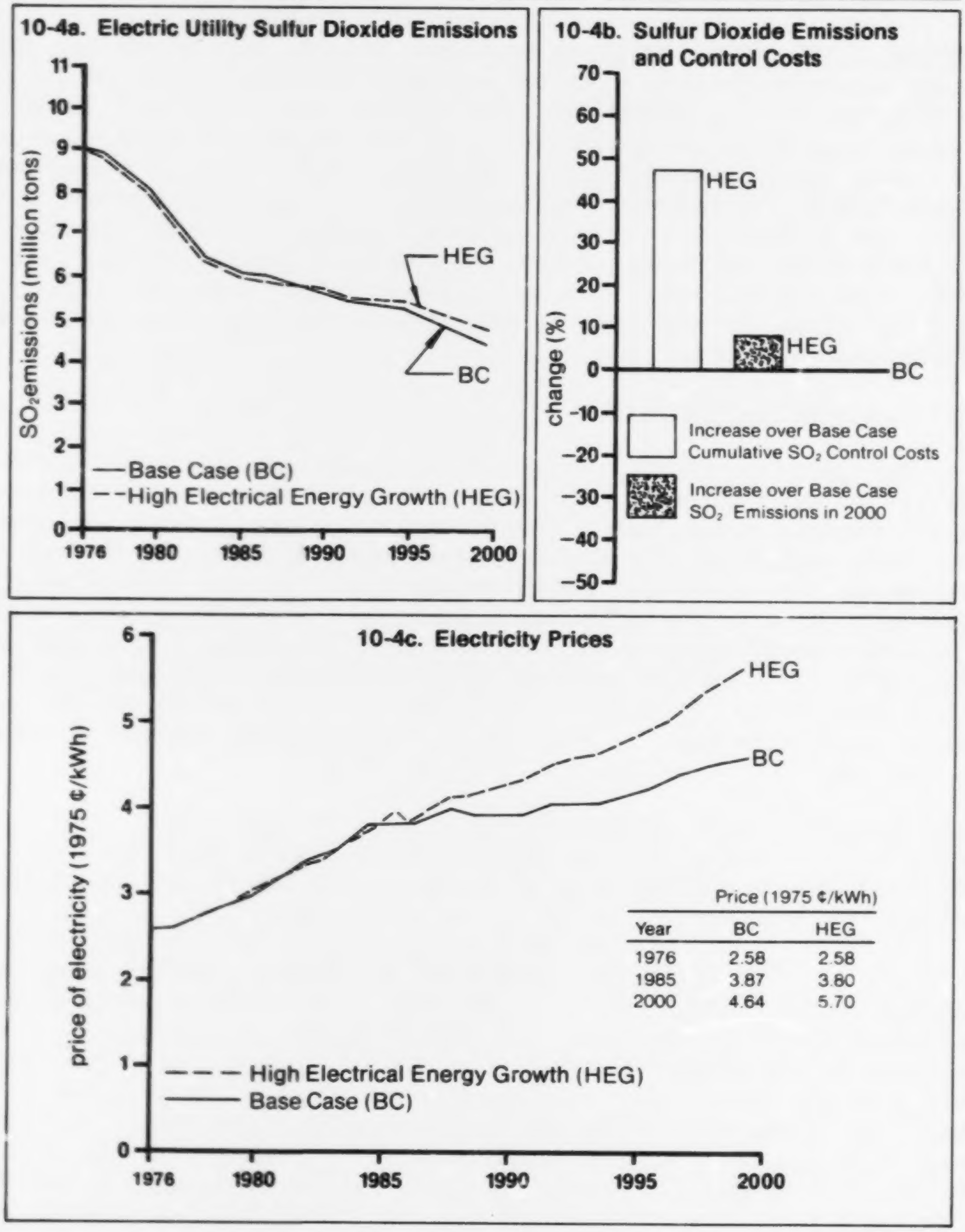
10.1.1 Air-Related Variations

Two variations of the high electrical growth case also were examined in the air quality analyses. One variation is identical to the high growth case in all respects except that a 35-year generating unit lifetime is assumed. This case, called the high-growth, 35-year case, is compared to the base case and to the high electrical energy growth case. In the second variation, generating units in the ORBES region are projected to come on-line, or to be dispatched, in the order of least sulfur dioxide emissions, rather than least cost, which is assumed in the high electrical energy growth case (and in all other scenarios). Otherwise, this latter variation, called the least emissions dispatch case, is identical to the high growth case and is compared to that case.

BASE CASE VERSUS HIGH GROWTH, 35-YEAR CASE. The high growth, 35-year case would result in nearly the same emissions and concentrations as those that are projected when a historic rate of growth in the demand for electricity is assumed (the base case).

In 1985, utility sulfur dioxide, particulate, and nitrogen oxide emissions under the high growth, 35-year case would be almost identical to the emissions under the base case. In 2000, however, utility sulfur dioxide, particulate, and nitrogen oxide emissions under the 35-year case would be 8.3, 10.5, and 23 percent higher, respectively, than those of the base case in that year (see figure 10-4a for sulfur dioxide emission comparisons). In terms of plant types, sulfur dioxide emissions from SIP-regulated plants would be similar in 2000 under both the high growth, 35-year case and the base case. This similarity would occur because the additional installed capacity under the former case is subject to revised new source performance standards (RNSPS), which are the strictest of all the standards. (RNSPS units would

Figure 10-4
Base Case versus High Electrical Energy Growth Case (35-Year Plant Life)



10-4a. Electric Utility Sulfur Dioxide Emissions

10-4b. Sulfur Dioxide Emissions and Control Costs

10-4c. Electricity Prices

	Price (1975 ¢/kWh)	
Year	BC	HEG
1976	2.58	2.58
1985	3.87	3.80
2000	4.64	5.70

provide about 67 percent of all coal-fired electrical generation in 2000 under the 35-year case.) Nevertheless, since each SIP unit emits five to six times more sulfur dioxide than a comparable RNSPS unit does, SIP emissions still would comprise the bulk of total emissions under the high growth, 35-year case, accounting for 2.9 million tons in 2000, or 62 percent of the 4.71 million tons emitted in that year.

Because utility sulfur dioxide emissions would be about the same in 1985 under both scenarios, utility-related annual and episodic sulfur dioxide and sulfate concentrations also would be about the same. In 2000, however, since emissions under the high growth, 35-year case would increase more between 1985 and 2000, utility-related annual and episodic concentrations would be somewhat higher under the high growth, 35-year case than under the base case. For example, annual utility-related sulfur dioxide and sulfate concentrations would be 13 percent and 18 percent higher, respectively, under the 35-year case in 2000 than they would be in the area of highest annual concentrations under the base case (see figures 10-5 and 10-6). Episodic sulfur dioxide and sulfate concentrations related to utility emissions would be 8 percent and 4.5 percent higher, respectively, under the high growth, 35-year case than they would be in the area of highest episodic concentrations under the base case.

Exclusive of pollution control costs, the cumulative cost of new coal-fired generating capacity through the year 2000 under the high growth, 35-year case would be 49 percent higher than under the base case. Cumulative pollution control costs would be 40 percent higher under the high growth, 35-year case than under the base case; cumulative capital costs for sulfur dioxide control would be 47.4 percent higher than such costs under the base case, and TSP control costs would be 25 percent higher. Figure 10-4b emphasizes the higher expenditures that would be necessary between 1976 and 2000 to keep sulfur dioxide emissions from being more than 8.3 percent higher in 2000 than under the base case.

In 1985, the price of electricity would be nearly identical under both the high growth, 35-year case and the base case (see figure 10-4c). In 2000, however, electricity prices would be about 23 percent higher under the high growth, 35-year case than under the base case. The cumulative revenues required from consumers between 1976 and 2000 because of these electricity prices would be 22 percent higher under the high growth, 35-year case than under the base case.

35-YEAR VERSUS 45-YEAR. One suggestion for achieving further emission reductions has concerned the reclassification of modified units. An estimate of the emission reductions possible under such a change can be made by comparing the emissions of the two high electrical energy growth cases--one with 35-year units and one with 45-year units.

Figure 10-5
Annual Average Sulfur Dioxide Concentrations, Electric Utility Contribution

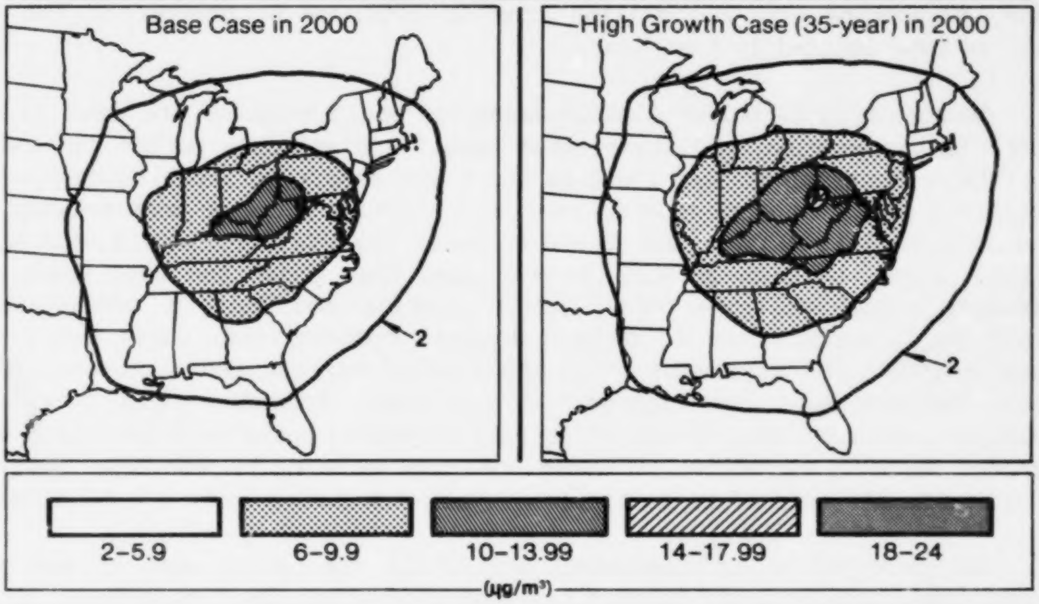
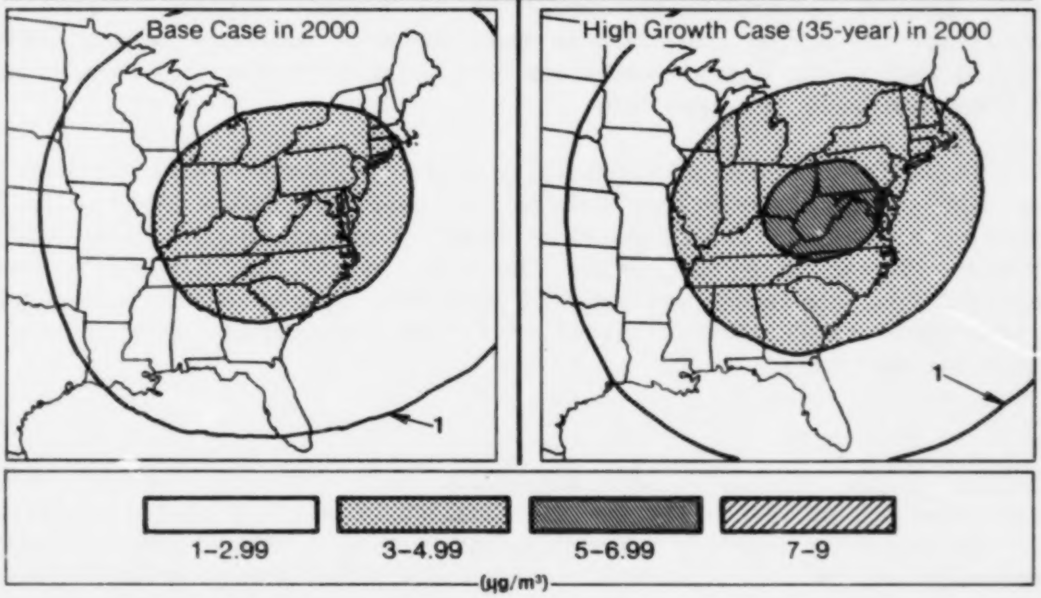

Base Case in 2000
High Growth Case (35-year) in 2000
2
2
2–5.9
6–9.9
10–13.99
14–17.99
18–24
(µg/m³)

Figure 10-6
Annual Average Sulfate Concentrations, Electric Utility Contribution


Base Case in 2000
High Growth Case (35-year) in 2000
1
1
1–2.99
3–4.99
5–6.99
7–9
(µg/m³)

Under both the 45-year plant lifetime case and the 35-year plant lifetime case, sulfur dioxide emissions from all generating units (SIP, NSPS, and RNSPS units) as well as those from SIP regulated units alone would be the same in 1985. In 2000, however, sulfur dioxide emissions from SIP-regulated units would total 4.32 million tons under the 45-year plant lifetime case; this amount is 49 percent higher than the 2.9 million tons emitted under the 35-year plant lifetime case. Sulfur dioxide emissions from all generating units (SIP, NSPS, and RNSPS) would total 6.06 million tons in 2000 under the 45-year plant lifetime case, or 29 percent higher than the 4.71 million tons emitted under the 35-year plant lifetime case (see figure 10-7). Thus, under high growth conditions, the retirement of SIP units could make a substantial difference in sulfur dioxide emission levels.

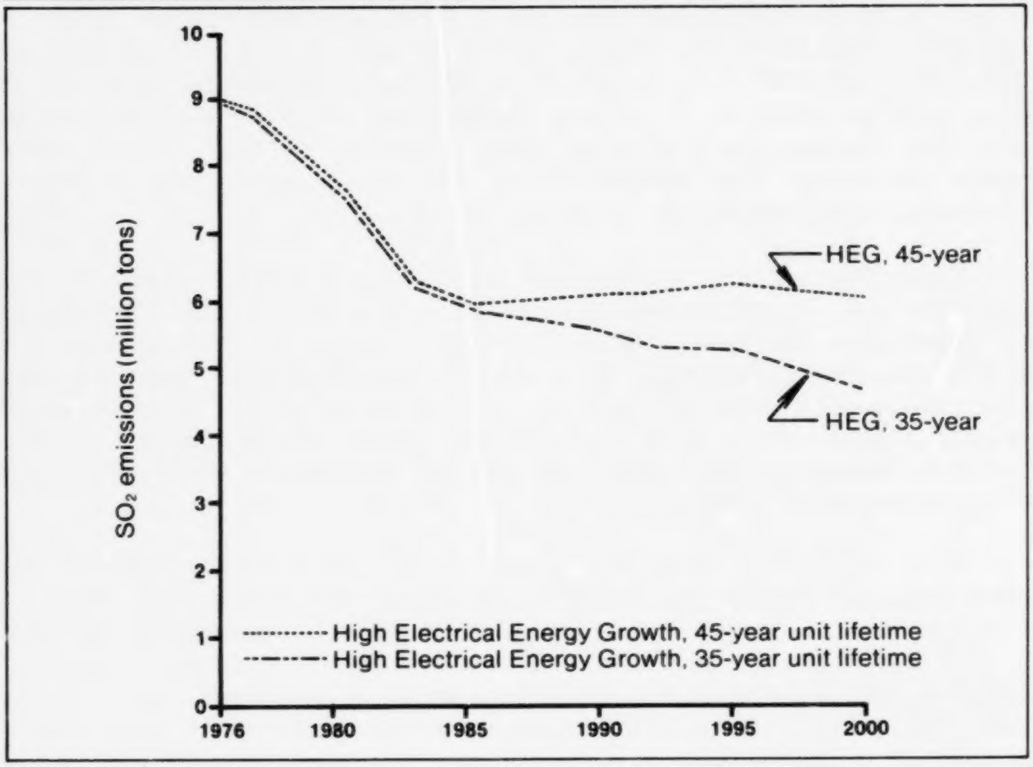
Similarly, utility particulate and nitrogen oxide emissions would be about the same in 1985 under both the 45-year plant lifetime case and the 35-year plant lifetime case. By 2000, however, under the 45-year case, utility particulate emissions would be about 24 percent higher than the emissions under the 35-year case, and utility nitrogen oxide emissions would be about 7 percent higher than under the 35-year case. Thus, again, under high electrical energy growth conditions, earlier retirements would have a positive impact on emission levels.

Early retirement also would result in significantly reduced utility-related sulfur dioxide and sulfate concentrations in the year 2000. In the area that would experience the highest sulfur dioxide concentrations under the 45-year case, episodic sulfur dioxide concentrations would be 21 percent lower and annual sulfur dioxide concentrations would be 42 percent lower in the year 2000. Similarly, episodic and annual sulfate concentrations under the 35-year case in 2000 in the same area would be 37 percent and 31 percent lower, respectively, than those under the 45-year case.

Because the 45-year lifetime assumption would permit the longer use of units and thus would result in fewer new units being built, the costs to both the utilities and to the consumer would be lower under the 45-year lifetime case than under the 35-year lifetime case. For the utilities, cumulative capital costs for new coal-fired generating capacity through the year 2000, exclusive of pollution control costs, would be about 10 percent lower under the 45-year lifetime assumption than under the 35-year lifetime assumption; cumulative pollution control costs would be 9 percent lower. In particular, cumulative capital costs for the control of sulfur dioxide emissions would be 9.3 percent lower under the 45-year case than under the 35-year case; the TSP control costs would be 8.2 percent lower under the former case than under the latter.

Costs to the consumer also would be lower under the 45-year unit lifetime case, although costs would not decrease as much for the consumers as they would for the utilities. In fact, the price of electricity would be the same

Figure 10-7
Electric Utility Sulfur Dioxide Emissions in the ORBES Region, High Electrical Energy Growth Case



for both cases in 1985. In 2000, electricity prices would be about 3 percent lower under the 45-year case than under the 35-year case. The cumulative revenues required from the consumer between 1976 and 2000 also would be lower (3.4 percent lower) under the former case than under the latter.

Overall, the 45-year generating unit lifetime assumption produces substantially higher utility sulfur dioxide and particulate emissions, lower cumulative capital costs for generating capacity and pollution abatement, and only slightly lower electricity prices. These tradeoffs are in contrast to those that would occur with a shorter plant lifetime: substantially lower emissions, higher utility costs, and only slightly higher electricity prices.

LEAST COST VERSUS LEAST EMISSIONS DISPATCH. However, there are ways to reduce sulfur dioxide emissions under high electrical energy growth while retaining the feature of longer plant lifetimes. For example, units with 45-year lifetimes could be dispatched according to the least amount of sulfur dioxide emissions rather than according to least cost. If such a dispatching order was implemented, utility sulfur dioxide, particulate, and nitrogen oxide emissions and utility-related regional sulfur dioxide and sulfate concentrations would be lower than under least cost dispatch.

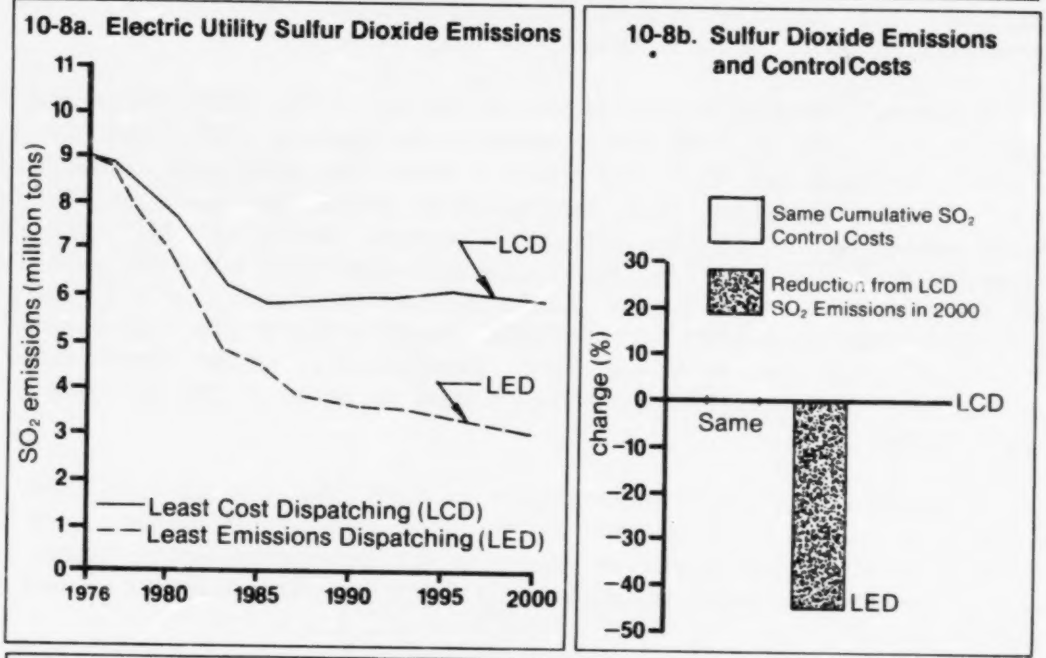
In general, utility sulfur dioxide emissions in the ORBES region would be significantly lower in 1985 and substantially lower in 2000 under the least emissions dispatch case than they would be under the least cost dispatch case. Sulfur dioxide emissions from SIP-regulated generating units in the ORBES region would be 24 percent and 65.3 percent lower in 1985 and 2000, respectively, under least emissions dispatch than they would be under least cost dispatch in the same years. Sulfur dioxide emissions from all generating units (SIP, NSPS, and RNSPS) in the ORBES region would be about 21 percent and 45 percent lower in 1985 and 2000, respectively, under least emissions dispatch than they would be under least cost dispatch in the same years (see figure 10-8a).

Utility particulate emissions would be about the same in 1985 under both assumptions (only 4 percent lower under least emissions dispatch). In 2000, however, utility particulate emissions would be significantly lower (19.2 percent) under the least emissions dispatch case than under the least cost dispatch case.

Nitrogen oxide emissions would be 5 percent lower in 1985 and 8.4 percent lower in 2000 under the least emissions dispatch case than they would be under the least cost dispatch case. The reason for this difference involves the assumption of nitrogen oxide standards for NSPS and RNSPS units in contrast to the absence of such standards for SIP units. Since NSPS and RNSPS units would be in service more of the time under least emissions dispatching, the least emissions dispatch case would lead to slightly lower nitrogen oxide emissions than the least cost dispatch case, in which SIP units are in service more of the time.

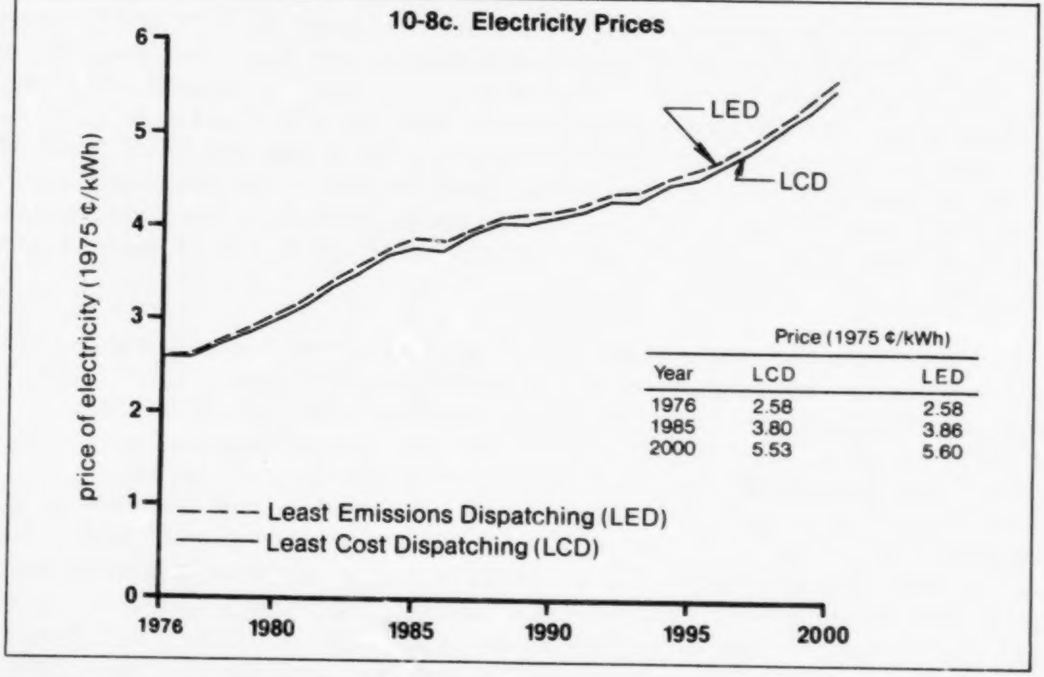
Annual regional sulfur dioxide and sulfate concentrations due to utility sulfur dioxide emissions would be significantly lower under the least emissions dispatch case than they would be under the least cost dispatch case. In 1985, in the area of highest concentrations, annual regional sulfur dioxide and sulfate concentrations due to utility sulfur dioxide emissions would be about 12 percent lower under least emissions dispatch than the concentrations projected under least cost dispatch. In 2000, annual regional sulfur dioxide and sulfate concentrations due to utility sulfur dioxide emissions would be about 42 and 31 percent lower, respectively, under least emissions dispatch than the concentrations projected under least cost dispatch (see figures 10-9 and 10-10). Episodic concentrations in the same area in the year 2000 also

Figure 10-8 Least Emissions Dispatching Case versus Least Cost Dispatching Case (High Electrical Energy Growth)



10-8a. Electric Utility Sulfur Dioxide Emissions

10-8b. Sulfur Dioxide Emissions and Control Costs



10-8c. Electricity Prices

	Price (1975 ¢/kWh)	
Year	LCD	LED
1976	2.58	2.58
1985	3.80	3.86
2000	5.53	5.60

Figure 10-9
Annual Average Sulfur Dioxide Concentrations, Electric Utility Contribution

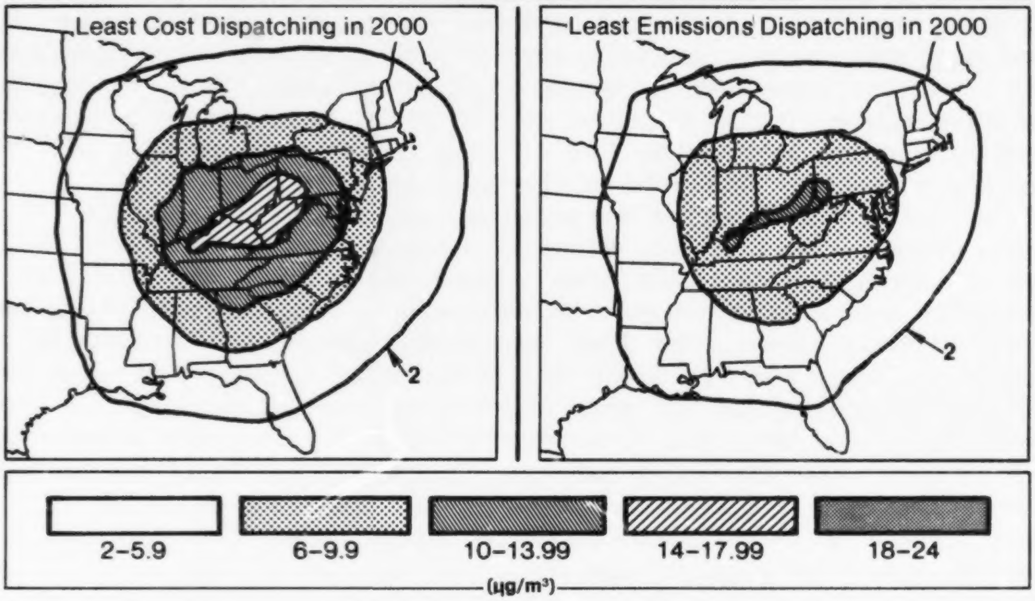
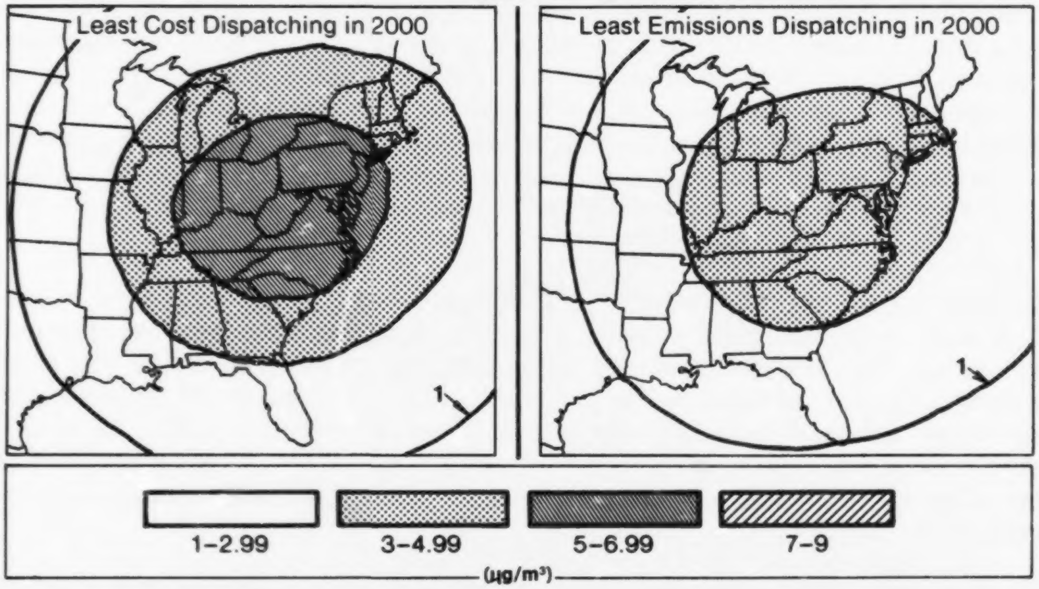

Least Cost Dispatching in 2000
Least Emissions Dispatching in 2000
2
2
2-5.9
6-9.9
10-13.99
14-17.99
18-24
(μg/m³)

Figure 10-10
Annual Average Sulfate Concentrations, Electric Utility Contribution


Least Cost Dispatching in 2000
Least Emissions Dispatching in 2000
1
1
1-2.99
3-4.99
5-6.99
7-9
(μg/m³)

would be lower under least emissions dispatching: episodic sulfur dioxide concentrations would be 51 percent lower, and episodic sulfate concentrations, 36 percent lower.

Since the same generating systems would be operated under both dispatching options, the cumulative capital costs of new coal-fired generating units and of pollution control devices would be the same. Thus, for the same cumulative sulfur dioxide pollution control costs, a 45 percent reduction in emissions could be achieved by 2000 if least emissions dispatching were used (see figure 10-8b). The major differences in costs between the two cases would be due to the increased operation and maintenance of pollution control devices required under least emissions dispatching and the increased fuel costs encountered under this case. These differences are reflected in electricity prices and revenues from consumers, although consumer costs would be only slightly higher under least emissions dispatching. For example, the price of electricity in 1985 would be 3.86 cents per kilowatt hour under least emissions dispatching and 3.8 cents under least cost dispatching. In 2000, electricity prices under the former case would be 5.6 cents per kilowatt hour and 5.53 cents under the latter case (see figure 10-8c). Thus, the cumulative revenues required from consumers between 1976 and 2000 would be only 1.5 percent higher under the least emissions dispatch case than they would be under the least cost dispatch case.

10.2 Land

The high electrical energy growth case with a 45-year generating lifetime would result in the greatest land use conversion and would have the highest terrestrial ecosystem unit assessment of any scenario analyzed. Similarly, substantially more area would be affected by utility-related sulfur dioxide concentrations of 130 micrograms per cubic meter than would be affected under the base case. As a result, it is estimated that agricultural losses due to regional utility sulfur dioxide emissions would be significantly higher than the losses projected under the base case. Agricultural losses due to oxidants formed from regional nitrogen oxide emissions also are projected to be higher under the high growth case.

LAND USE. Under the high electrical energy growth case, land converted for all energy uses (new generating facilities, new transmission line rights-of-way, and new surface mining for utility coal) in the ORBES region would total approximately 1.1 million acres by 2000. This acreage is 12 percent higher than under the base case and represents 1 percent of the total land in the region. Although the percentage of regional acreage affected by such conversion is quite small, the percentage of county acreage affected could be significant.

Among the ORBES scenarios, the greatest land conversion for electrical generating facilities also would occur under the high electrical energy growth case (29 percent higher than under the base case). In terms of the ORBES state portions, the West Virginia portion would experience the largest increase in land use (61 percent) over the amount required under the base case since 11 more generating units are sited in that state portion than are sited under the base case. The percentage increases over the base case of the five other ORBES state portions would range from 8 percent in Pennsylvania to 42 percent in Ohio.

In terms of the land types converted to install the high growth energy capacity, substantially more forest land (32 percent more) and agricultural land (25 percent more) would be converted under the higher electrical energy growth case than under the base case. Similarly, 31 percent more public land and 42 percent more other types of land would be converted than under the base case.

Under high electrical energy growth, substantially more land would be affected than under the base case by utility-related sulfur dioxide concentrations of 130 micrograms per cubic meter. Although nearly the same amount of land would be affected in 1985 under both the high growth case and the base case, 49 percent more land would be affected in 2000 under the former case than under the latter. Thus, while the acreage affected by such concentrations under the base case in 2000 would represent 3.1 percent of the ORBES region, such concentrations would affect 4.5 percent of the region in 2000 under the high electrical energy growth case.

PHYSICAL CROP LOSSES. Regional agricultural losses due to such sulfur dioxide concentrations in the presence of moderate ozone levels are estimated to be higher under the high electrical energy growth case than the losses projected under the base case. In the year 2000, the regional losses under the high growth case would range from a minimum of 289,000 bushels to a maximum of 2 million bushels, with 1 million bushels representing the probable loss. Under the base case, the range in 2000 would be from 248,000 bushels to 1.7 million bushels.

As under the base case, agricultural losses under the high growth case would represent less than 1 percent of the regional clean air yield. However, on a local scale, such as the county, losses could be significant, and losses to individual farmers substantial. For example, as under the base case, the ORBES state portion of Illinois would account for most of the regional crop losses--from 59 to 74 percent in 2000, depending on the crop--and the state portions of Illinois, Indiana, and Ohio would account for 95 percent of all losses.

Regional agricultural losses due to ozone formed from regional nitrogen oxide emissions in combination with other pollutants would be higher under the high growth case in the year 2000 than under the base case in that year. As will be recalled, nitrogen oxide emissions from transportation are projected to decline after 1985 while nitrogen oxide emissions from the electric utility sector are projected to increase. Under the high growth case, these utility emissions would increase even more than they would under the base case. As a result, high growth utility emissions would exceed the decreases in transportation emissions. Thus, more nitrogen oxide emissions would exist for ozone formation under the high growth case than under the base case. Correspondingly, agricultural losses due to such ozone formation would increase.

Under the high electrical energy growth case, oxidant-related agricultural losses in 2000 would range from a minimum of 370 million bushels to a maximum of 705 million bushels, with 468 million bushels representing the probable losses. These probable loss projections are approximately 173 percent higher than the probable losses projected to occur under the base case in 2000.

MONETARY CROP LOSSES. Between 1976 and 2000 under the high electrical energy growth case, cumulative probable agricultural dollar losses attributable to regional utility sulfur dioxide emissions and to oxidants formed from regional nitrogen oxide emissions would be about 20 percent higher than such losses under the base case. The distribution of dollar losses among crops and the ORBES state portions would be almost identical under both the high electrical energy growth case and the base case.

TERRESTRIAL ECOSYSTEMS. The high electrical energy growth case would result in the highest number of regionwide terrestrial ecosystem units between 1976 and 2000 of all the scenarios. The unit total under high growth would be 33 percent higher than the unit total under the base case between those years. All the ORBES state portions would have more terrestrial ecosystem units assessed under the high electrical growth case than under the base case. The increase in unit totals would range from about 18 percent in the ORBES portion of Indiana to 60 percent in the ORBES portion of West Virginia.

FOREST LOSSES. Forest losses also are projected to be higher in the year 2000 under the high growth case. Under this case, the estimated annual reduction in forest growth by 2000 due to air pollutants, principally ozone, would be from 2.1 to 9.3 percent of the total production. In 2000 under the base case, the reduction in forest growth would range from 0.4 to 1.9 percent of the total production.

10.3 Water

Under the high electrical energy growth case with a 45-year generating unit lifetime, 144 coal-fired units--each 650 megawatts electric--are sited; 142 ultimately would affect the Ohio River main stem, while 2 are on the Susquehanna. However, again, as under the base case, the majority of the impacts would be due to high background concentrations either alone or in conjunction with municipal and industrial consumption. Since so many units are sited under the high growth case, some are sited on the region's smaller streams. As discussed previously, these streams generally are not suitable for the siting of even 650 megawatt plants because of their high background concentrations and their low flow per second under 7-day-10-year low flow conditions. As a result, more streams would be affected by power plant consumption under the high growth case than under any other scenario.

For a majority of the streams, however, aquatic habitat impacts under the high electrical growth case and 7-day-10-day low flow would be about the same as they would be under the base case and such low flow conditions (see table 10-1). For three streams, however, aquatic habitat impacts under the high electrical growth case would be severer than they would be under base case conditions.

The streams that would be affected by high background concentrations in conjunction with power plant consumption under the base case--the Allegheny, the Big Muddy, and the Illinois--also would be affected because of high background concentrations in conjunction with power plant consumption under the high growth case. Three additional rivers--the Big Sandy, the Great Miami, and the Little Miami--also would be affected by such concentrations and consumption under the high growth case. These three rivers, all of which would undergo heavy aquatic habitat impacts under base case conditions, would undergo drastic impacts under the high electrical growth case, in which two or more standard generating units are sited on each river.

Under high growth, six additional streams would experience incremental increases in their base case water quality index values because of additional installed capacity. However, these six rivers--the Beaver, the Kanawha, the Monongahela, the Muskingum, the Wabash, and the White--would have the same protection levels and aquatic habitat impacts as under the base case. Moreover, high background levels in conjunction with municipal and industrial consumption would cause the majority of these rivers' problems under both scenarios. Thus, for example, when one more unit is sited on the Beaver under the high growth case, the water quality index value changes from 35 under the base case to 40 under the high growth case (see table 10-1). This change indicates that a few more water quality parameters would be violated with this additional siting. However, such violations would not be significant enough to cause changes in the aquatic habitat impacts, although additional stress might be experienced on this river.

To alleviate the impacts related to power plants projected under the high electrical energy growth case would require some of the same tradeoffs discussed in chapter 6. Alternative siting of the units could make a substantial difference on such small rivers as the Little Miami and could alleviate the stress on such rivers as the Allegheny. However, since such a

Table 10-1
Aquatic Habitat Impacts, Base Case versus High Electrical Energy Growth Case, 7-Day–10-Year Low Flow, Year 2000

River	Better (+) Worse (−) Same (0) As Base Case Habitat Impacts	Water Quality Impact Index (range: 0 to 100) if changed	Change in Base Case Protection Levels	Change in Base Case Habitat Impacts	Number of Units Added or Removed from Base Case
Allegheny	0				
Beaver	0	40			+ 1
Big Muddy	0				
Big Sandy	−	70	D	Drastic	+ 2
Cumberland	0				
Great Miami	−	58	D	Drastic	+ 4
Green	0				
Illinois	0				+ 1
Kanawha	0	35			+ 4
Kaskaskia	0				
Kentucky	−	−	*	−	+ 5
Licking	0				
Little Miami	−	65	D	Drastic	+ 2
Mississippi	0				
Monongahela	0	36			+ 1
Muskingum	0	41			+ 2
Ohio Main Stem	0				+14
Rock	−	−	*	−	
Salt	−	−	*	−	
Scioto	0				
Susquehanna	−	−	*	−	+ 1
Wabash	0	26			+ 2
White	0	32			+ 3
Whitewater	−	−	*	−	+ 2

*Background data unavailable; analysis could not be completed.

large generating capacity is projected under the high growth case, suitable alternative sites are more limited under this case than under the other scenarios. In general, alternative siting under this case probably would result in a high concentration of units along the Ohio main stem. This concentration would in turn exacerbate the air quality problems that already exist in that area.

10.4 Employment

A high electrical energy growth rate along with a 45-year generating unit lifetime would result in a vigorous rise in the employment of power plant construction workers in the ORBES region. However, the very large increase in power plant construction over a short period of time could induce critical construction labor shortages. In contrast, no regional shortages would be expected under base case conditions.

Between 1975 and 1995 under the high electrical energy growth case, the total demand for power plant construction and operation workers--as measured by person-years--would be about 32 percent higher than the demand projected under the base case. Between 1983 and 1985, there would be a 60 percent rise in employment demand under high electrical energy growth. This dramatic rise would not occur under the base case.

To construct the power plants projected under high electrical energy growth, substantially more boilermakers and slightly more electricians and pipefitters would be required than probably could be supplied. The resulting shortages could cause construction delays, in-migration of labor from other regions, and/or labor shortages in other industries. Under the base case, no such shortages would be expected. In fact, in 1990, the peak construction year, the demand for such specialized labor would be from 67 to 73 percent higher under the high growth case than the demand under the base case in 1990, depending on the skill involved.

10.5 Health

Since coal-fired capacity would be the same in 1985 under both the base case and the high electrical energy growth case, the health impacts of the coal-mining and coal-processing sectors would be the same in that year under both cases. However, because coal-fired capacity under high growth would be significantly greater by 2000 than the capacity under the base case in that year, so would the health impacts related to supplying coal to this increased capacity. Accidental and disease-related deaths and injuries in the coal-mining and coal-processing sectors would be about 18.2 percent higher by the year 2000 than such deaths and injuries under the base case in that year.

Because air pollutant emissions would increase significantly between 1985 and 2000 under the high electrical energy growth case, more cumulative deaths are projected to occur between 1975 and 2000 from sulfate and particulate air pollution by ORBES-region electrical generating facilities. Under the high growth case, the cumulative deaths associated with sulfate air pollution are projected to be 13 percent higher. The yearly deaths associated with sulfate air pollution would be only 3 percent higher in 1985 under the high growth case than under the base case. In 2000, however, yearly deaths would be 46 percent higher under the former case than under the latter. The cumulative deaths associated with particulates between 1975 and 2000 are projected to be 46 percent higher under the high growth case than under the base case.

11. Impacts of the Electrical Exports Case

In this chapter, the impacts of the electrical exports case are compared with base case impacts in all five impact areas (air, land, water, employment, and health).

The electrical exports case has many of the same assumptions as the base case. For example, the same environmental controls are assumed. The primary difference between the two scenarios lies in the assumed electricity demand growth rate. The higher rate under the electrical exports case (an average annual rate of 3.2 percent, compared with 3.13 percent under the base case) results from the assumption that there will be a major increase in the amount of electricity exported from the ORBES region. Because of the expanded coal-fired electrical generating capacity under the exports case, other fuel use characteristics also are different from those under the base case. See chapter 5 for details.

11.1 Air

Because more coal-fired units would be sited in the ORBES region between 1985 and 2000 under the electrical exports case than under the base case, regional utility sulfur dioxide, particulate, and nitrogen oxide emissions would be higher in 2000 under the exports case than they would be under the base case.[1] However, the increase would be small because it is assumed that all exported power will be supplied by units governed by the revised new source performance standards (RNSPS), which are the strictest of the three standards (state implementation plans (SIPs), new source performance standards (NSPS), and RNSPS). Thus, in the year 2000 utility sulfur dioxide emissions from all generating units in the ORBES region would be only 4.6 percent higher under the exports case than under the base case, and utility particulate emissions would be about 5.3 percent higher under the former case than under the latter in that year. Finally, utility nitrogen oxide emissions in 2000 would be about 11 percent higher under the exports case than under the base case.

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[1] For calculations of emissions, pollution control costs, and capital costs under the electrical exports case, see Teknekron Research, Inc., The Calculation of Several Measures for ORBES Scenarios 2a, 2, and 6 (RM-032-EPA-80, June 1980).

With the increased export of coal-fired electricity from the region, cumulative pollution control costs through the year 2000 would be about 15 percent higher than they would be under the base case. The costs of controlling utility sulfur dioxide emissions would be about 18 percent higher, and the costs of controlling utility particulate emissions would be about 9.5 percent higher. Cumulative capital costs of installing the coal-fired generating capacity under the electrical exports case would be about 22 percent higher than the costs of installing base case coal-fired capacity, exclusive of pollution control costs. However, the ratio of pollution control costs to the total costs of installing new capacity and pollution control devices would be nearly identical for both scenarios. Thus, the rise in pollution control costs under the exports case would result entirely from the larger installed capacity.

11.2 Land

Under the electrical exports case, regionwide land use requirements for electrical generating facilities and for surface mining would be significantly higher than base case requirements. More terrestrial ecosystem units likewise would be assessed under the former case than under the latter.[2]

The electrical exports case would require 17 percent more land for electrical generating facilities between 1976 and 2000 than would the base case. Most of this increase would occur in the ORBES state portions of Ohio, Pennsylvania, and West Virginia--the ORBES states closest to the northeastern United States, the destination of the exported electricity. The increase in land use requirements for generating units within these state portions would be greatest in West Virginia (65 percent), followed by Ohio (45 percent) and Pennsylvania (20 percent).

In terms of the types of lands converted under the electrical exports case for electrical generating facilities, 29 percent more public lands would be converted between 1976 and 2000 than would be converted under the base case. Increases also would occur in the conversion of other types of land: 27 percent more forest land, 9 percent more agricultural land, and 21 percent more other types of land.

The electrical exports case also would result in an increase in surface mining for utility coal; more acres in the ORBES region (8 percent) would be affected by such surface mining in 2000 under the exports case than under the base case. The ORBES state portion of Ohio would have the most acreage affected by this increased surface mining for utility coal (28 percent of the total acres affected under the exports case); the state portion of Illinois, the least (7 percent). The surface mining of coal for all purposes within the ORBES region would be about 6 percent higher between 1976 and 2000 under the electrical exports case than under the base case.

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[2] See the corresponding sections of chapter 7 for references to the ORBES reports consulted for this section and the following ones.

Seventeen percent more terrestrial ecosystem units would be assessed under the electrical exports case than under the base case. The unit assessment would be highest in the ORBES state portions of Ohio (42 percent higher than the base case assessment), Pennsylvania (22 percent higher), and West Virginia (65 percent higher), where most of the additional facilities are sited to reduce transmission losses.

11.3 Water

Under the electrical exports case, aquatic habitat impacts under 7-day-10-year low flow conditions would not be different from the impacts under the base case and these conditions for any of the rivers selected for detailed analysis (see table 11-1). Thus, as may be recalled from the discussion of impacts under the base case (see section 7.3), aquatic habitat impacts under the exports case would occur primarily because of high background concentrations either alone or in conjunction with municipal and industrial consumption; power plant consumption would have a minor impact on most streams. Only the Allegheny and the Big Muddy rivers would experience impacts attributable to high background levels in conjunction with power plant water consumption under the exports case--as they would under the base case. Two other rivers--the Muskingum and the Scioto--would register incremental increases in their water quality indices, suggesting that additional violations of parameters would occur because of the additional installed capacity. However, these violations would not be significant enough to cause a change in aquatic habitat impacts, although additional stress could be experienced by both rivers, which already were projected to experience heavy impacts under the base case.

A variation of this scenario also was developed to explore the potential water quality impacts that would occur if once-through cooling, rather than cooling towers, was used for the 82 units sited on the main stem of the Ohio River under the electrical exports case. Other than this change, the once-through cooling variation has the same energy and fuel use characteristics as the exports case with cooling towers.

If once-through cooling were to be used for the 82 coal-fired, 650 megawatt electric units added by the electrical exports case on the Ohio River main stem, water withdrawal would increase drastically. This increase could have a devastating entrainment-impingement impact on the main stem at 7-day-

Table 11-1
Aquatic Habitat Impacts, Base Case versus Electrical Exports Case, 7-Day–10-Year Low Flow, Year 2000

River	Better (+) Worse (–) Same (0) As Base Case Habitat Impacts	Water Quality Impact Index (range: 0 to 100) if changed	Change in Base Case Protection Levels	Change in Base Case Habitat Impacts	Number of Units Added or Removed from Base Case
Allegheny	0	34			+ 4
Beaver	0				+ 1
Big Muddy	0				
Big Sandy	0				
Cumberland	0				
Great Miami	0				
Green	0				
Illinois	0				
Kanawha	0				
Kaskaskia	0				
Kentucky	–	–	*	–	
Licking	0				
Little Miami	0				
Mississippi	0				
Monongahela	0				
Muskingum	0	41			+ 2
Ohio Main Stem	0				+22
Rock	–	–	*	–	
Salt	–	–	*	–	
Scioto	0	40			+ 2
Susquehanna	–	–	*	–	
Wabash	0				
White	0				
Whitewater	–	–	*	–	

*Background data unavailable; analysis could not be completed.

10-year low flow. Temperature impacts under once-through cooling would be damaging locally, especially to sensitive bank habitats, although once-through cooling would not affect the total river temperature. Such local temperature impacts would be nonexistent under the electrical exports case with cooling towers. Finally, a dissolved oxygen sag would be observed along the first 50 miles of the main stem with the use of once-through cooling; levels would return to seasonal norms below that point.

11.4 Employment

Employment would increase under the scenario in which electricity is exported from the ORBES region to the middle Atlantic states. Such export of power would require the concentrated construction of a large number of power plants in the eastern portion of the ORBES region over a short period of time. As a result, the demand for construction workers would be dramatically higher than the demand under base case conditions. Dramatic increases also would be expected in coal-mining employment.

Between 1975 and 1995 under the electrical exports case, about 20 percent more person-years would be required for power plant construction and operation than would be required under the base case. Between 1983 and 1985 in particular, there would be a precipitous rise, over 60 percent, in the number of workers needed for power plant construction under the exports case. In 1990, about 45 percent more workers in each of the three critical skill categories examined would be needed than under the base case in that year. The intensity of this demand would last until 1994, the peak construction year under the electrical exports case.

To meet the increased need for coal under the electrical exports case, annual coal production for all purposes would be about 10 percent higher by the year 2000 than the levels projected for the base case in that year. Electrical generating units also would be consuming 14 percent more coal under the exports case in 2000 than under the base case in that year.

Given these increases in coal production and in electric power coal consumption under the exports case, coal-mining employment in the ORBES region for all purposes would increase between 42 and 270 percent from 1970 to 2000, compared with between 35 and 222 percent under the base case. At least 47 of the 152 coal-producing counties in the region would experience mining employment growth rates between 50 and 199 percent. Also, an additional 88 counties might experience rates over 200 percent and, thus, boom-town effects. In comparison, under the base case at least 55 counties would experience rates between 50 and 199 percent, and 79 would experience rates greater than 200 percent.

11.5 Health

The number of deaths and injuries related to coal mining and coal processing would be about 15 percent greater by 2000 under the electrical exports case than under the base case in that year. Due to the fact that the same electrical generating capacity is assumed for both scenarios in 1985, the number of such deaths and injuries would be the same under both scenarios in that year.

12. Mitigation Strategies

The five energy-environmental futures, or scenarios, discussed in previous chapters are based on the central assumption that, through the year 2000, coal will continue to be the dominant fuel for the generation of electricity in the Ohio River Basin Energy Study (ORBES) region. The scenarios whose impacts are set forth and contrasted assume, respectively: (1) base case conditions, (2) stricter environmental controls, (3) noncompliance with state implementation plans (SIPs), (4) high electrical energy growth, and (5) a significant increase in the export of electricity from the region.

The analysis of the coal-dominated futures reveals that, among all the impacts identified, those on air quality would be affected the most by the various scenario policies examined. The analysis shows that certain economic and health effects are associated with the air quality impacts. The health impacts are related to air pollutant concentrations, while the economic impacts are associated with the cost of air pollution control and the dollar losses associated with decreases in agricultural yields due to air pollution. Impacts on water quality due to coal-fired electrical generating facilities would be relatively insignificant on a regional basis. However, a number of severe impacts might occur because of water consumption by industries and municipalities under 7-day-10-year low flow conditions and current pollutant levels. Impacts on land use and on employment would be relatively minor, although in some areas coal-mining employment might increase significantly.

Since institutional mechanisms exist to handle impacts in all areas but those related to air quality, the major purpose of this chapter is to offer examples of strategies that might be utilized to mitigate impacts on air quality at the interstate-regional level. It should be emphasized that under all the ORBES scenarios--including the SIP noncompliance case and the high electrical energy growth case--overall regional emission levels of both sulfur dioxide and particulates would be lower in the year 2000 than in 1976. Emissions of oxides of nitrogen, however, would be higher under all the scenarios.

Despite the emission reductions projected in the ORBES scenarios at the regional level, pollutant concentrations still would be a problem at local "hot spots." Moreover, episodic conditions still would lead to high concentrations both within and beyond the study region. The reason for this continuing problem lies in local and long-range transboundary air pollution transport. Thus, this chapter focuses on a variety of strategies to mitigate these negative impacts.

12.1 Coal Impact Mitigation

Strategies to mitigate air quality impacts are numerous and can be classified in many different ways. The approach taken here groups mitigation strategies into two categories, technical and techno-organizational. The first category, technical strategies, includes methods that can be applied at a single generating unit. The second category, techno-organizational strategies, acknowledges the importance of technology but stresses that the technology is applied within a broader organizational context.[1]

Although this study emphasizes impacts and strategies in the ORBES region, it is quite possible that extraregional impacts could be more significant than either local or regional conditions in determining future air quality mitigation strategies. Even though the ORBES region is critical for the production of electricity, it also is part of a broader natural region that ranges eastward from the Mississippi River to the Atlantic coast and encompasses nearly half of the nation's land area. In this broader area, other sections besides the ORBES region also are important for the generation of electricity and for overall air quality. For example, it is difficult to consider air quality strategies for the ORBES region independent of the area served by the Tennessee Valley Authority (TVA), especially since the ORBES region overlaps the TVA service area in portions of Kentucky. More important, perhaps, is the fact that air masses from the two regions mix and often move toward the northeastern United States and southwestern Canada. This transboundary air pollution transport could be the impetus for the development of joint strategies to mitigate negative impacts.

12.1.1 Technical Strategies

A number of technical strategies to mitigate negative impacts on air quality are assumed in the ORBES scenarios. Traditionally, such strategies are applied on a plant-by-plant basis, with little or no attempt at coordination.

SCRUBBERS. An obvious example of a technical strategy is the use of flue gas desulfurization systems, or scrubbers, on coal-fired generating facilities. This option could be very effective for the ORBES region, as shown in the scenario analysis.

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[1] See Boyd R. Keenan, Ohio Basin Interstate Energy Options: Constraints of Federalism (ORBES Phase II), for discussions of both technical and techno-organizational strategies.

RECLASSIFICATION. Another technical strategy centers around boiler maintenance programs, which are a vital part of utility operations. Many of these programs cause an existing installation to be upgraded to such an extent that they are comparable to new installations in a number of respects. It has been suggested that certain extensive maintenance activities, such as the successive replacement of boiler tubes, should result in the reclassification of a unit from an existing source of pollution to a new source (Clean Air Act, sec. 111). This suggestion is made because existing boilers operate under less stringent emission regulations. Since the less stringent emission regulations also are less costly to implement, often it is attractive to the utility to operate large existing installations as long as possible. The effect of this prolonged plant life is evaluated in chapter 10 in reference to high electrical energy growth conditions.

If extensive modifications were to result in the reclassification of an installation from an existing to a new source, then economic decisions regarding the useful lifetime of a plant would have to be made very early in that plant's period of operation. In some cases, existing plants might be retired early and replaced by new ones.

12.1.2 Techno-Organizational Strategies

The technical mitigation strategies reviewed above usually are applied on a plant-by-plant basis. The term techno-organizational is used here to describe broader strategies that already are available or that could be developed on an interstate, multistate, or regional scale.

Transboundary air pollution transport can be separated into two basic types. These are (1) local transboundary air pollution transport, where air masses move over relatively short distances across state lines and the contributions from individual plant sources usually can be identified, and (2) long-range transboundary air pollution transport, where air masses travel longer distances (often across several state lines) and the contributions from individual sources are difficult to isolate. Often it is unclear which of the two types is involved: at power plant sites, as elsewhere, the meteorology changes from hour to hour. Wind, temperature, rain, and topography all contribute to changes. In general, emissions cannot be identified as being from a particular plant more than about 30 miles (50 kilometers) away. Occasionally, however, the meteorology is such that emissions can be traced to a particular plant at considerably longer distances.

12.1.2.1 Local Transboundary Air Pollution

Because the sources of local transboundary pollution can be identified, it was possible to include provisions in the Clean Air Act that attempt to make a state responsible for pollution that originates within its borders but is transported short distances into other states (secs. 110, 126, and 160). These provisions constitute a legal framework that can help remedy disputes that arise from local transboundary pollution.

SECTION 126. Basic in such disputes is section 126, "Interstate Pollution Abatement," which specifies the procedures for a state or its political subdivisions to seek action from the U.S. Environmental Protection Agency against operators of sources in other states. In at least three cases, ORBES state officials have filed formal petitions against neighboring states with the EPA administrator; it is believed these petitions represent the only formal efforts in the entire country to utilize the petitioning provision of section 126.

The first petition was filed by the state of Kentucky. In July 1979, EPA hearings were held to pursue the state's claim that sulfur dioxide emissions from an Indiana plant are affecting Kentucky's efforts to comply with air quality standards in the area immediately across the Ohio River from Madison, Indiana. The facility in question is the Clifty Creek plant, operated by the Indiana-Kentucky Electric Corporation, a consortium of investor-owned companies. EPA now is in the process of considering the Kentucky petition.

The second instance where the interstate petition procedure of section 126 has been utilized also involves a claim by a Kentucky unit of government against a source in Indiana. In December 1979, the Jefferson County Air Pollution Control District in Louisville petitioned EPA. This petition argues that the Gallagher power plant, operated in southern Indiana by Public Service Indiana, is frustrating Kentucky's efforts to maintain air quality standards and to assure industrial growth in that state. At issue are the extremely different air quality standards in effect in Jefferson County, Kentucky, and Floyd County, Indiana. Although the two counties are separated only by the Ohio River, standards for Jefferson County are considerably stricter than those for Floyd County.

Hearings on the Gallagher situation were held by EPA in April 1980; an announcement of the findings is expected soon. The problem may be linked to that of Clifty Creek, which is located only 40 miles away. That is, it may be necessary to determine the contribution of emissions from Clifty Creek to air quality degradation in the vicinity of Gallagher.

The final known instance of a state's seeking remedy under the petition provision of section 126 is an action taken in 1978 by West Virginia against a plant in Ohio. That facility, the W.H. Sammis plant, is operated by the Ohio Edison Company at Stratton, Ohio, across the Ohio River from New Manchester, in the northern "panhandle" of West Virginia. The action on the Sammis plant is believed to be the first in the nation filed under section 126. As with the two other petitions noted above, no final resolution has been reported.

In addition to allowing action against existing sources, section 126 of the Clean Air Act also prohibits a state from approving construction of new facilities whose emissions would prevent another state from attaining or maintaining national ambient air quality standards. Similar petitioning and public hearing procedures as for existing sources are provided. For both kinds of actions, of course, states have the final recourse of judicial review.

PATRIOT. Despite the framework for addressing local transboundary pollution transport questions provided by the Clean Air Act, protracted legal conflicts between ORBES states have taken place. One of the most illustrative in revealing the complexity of local transboundary pollutant transport took place in the late 1970s; it concerned the siting of a proposed electrical generating facility on the Indiana side of the Ohio River.

The case began with the announcement by the Indianapolis Power and Light Company (IPL) of its intention to build three 650 megawatt electric units on an 884-acre site in southeast Indiana. Located southwest of Cincinnati, about 50 miles downstream on the Ohio, the site is near the Indiana town of Patriot in Switzerland County. Across the river is Boone County, Kentucky, where two Ohio-based utilities, the Cincinnati Gas and Electric Company and the Dayton Power and Light Company, operate the East Bend plant.

In May 1978, Kentucky officials informed EPA of modeling results indicating that, in conjunction with the existing East Bend facility, the Patriot facility proposed by IPL would cause the allowable PSD increments for sulfur dioxide to be exceeded in Kentucky. Taking the Kentucky modeling results into consideration, EPA Region V disapproved construction of Patriot in August 1978 by denying a PSD permit, which is required under section 160 of the Clean Air Act.

After the EPA decision, IPL petitioned the U.S. Court of Appeals, Seventh Circuit, to review the matter (Indianapolis Power and Light Company v. U.S. Environmental Protection Agency, docket no. 78-2062, filed October 2, 1978). The utility company also asked the court for a temporary injunction to prevent EPA from approving permits sought by other electric utility companies in the area. Apparently, IPL feared that the EPA Region IV offices in Atlanta would grant the other utilities a permit to expand the East Bend plant. This effort is believed to represent the first time in American history that an electric utility in one state has fought in federal court to "stake its claim" for clean air before a utility in a neighboring state could make its own claim. In October 1978, the Court of Appeals denied IPL the temporary injunction.

After the case was argued in the court of appeals, EPA admitted error based on misinterpretation of the Kentucky modeling data. On May 21, 1979, at EPA's suggestion the court remanded the proceedings to the agency for administrative ruling. Finally, EPA reversed itself and awarded the permit. But the permit was awarded only after extensive technical arguments involving the court, EPA, both states, and the utility affected. The cost of the negotiations, in terms of both time and money, was apparently considerable to both public and private parties to the dispute.

This case shows how interstate conflicts can arise over power plant siting. Often it is cited in discussions of possible mechanisms that might both avoid such disputes and preserve air quality in a "local" two or three-state area. Three-state configurations are particularly complex. In the ORBES region, conflict over transboundary air pollution transport could occur in several tristate areas, including (1) West Virginia's northern panhandle, a portion of Ohio, and a part of Pennsylvania, (2) the area around Huntington, West Virginia, and Ashland, Kentucky, which includes portions of those two states, plus Ohio, and (3) the Cincinnati area, which includes portions of Ohio, Kentucky, and Indiana.

In these and other interstate areas of the ORBES region, certain federal structural patterns, particularly EPA's organizational structure for regulatory functions, do not promote communication among the states. The ORBES states fall into three different EPA regions: Region III (offices in Philadelphia), with responsibility for Pennsylvania and West Virginia; Region IV (Atlanta), with responsibility for Kentucky; and Region V (Chicago), with responsibility for Illinois, Indiana, and Ohio. EPA has responded to the difficulties associated with air quality management in the Ohio River Valley and the broader ORBES region by creating a tri-regional task force. Comprised of the three regional administrators, the body's primary objective is to strengthen cooperation in meeting interstate and interregional air quality issues.

12.1.2.2 Long-Range Transboundary Air Pollution

As noted above, the distinguishing characteristic of long-range transboundary air pollution is that emissions transported across state lines, although capable of being measured, cannot be identified with a particular source. There is ambiguity within legal circles as to whether individual plant sources must be distinguished before legal actions can be brought by one state against another under the Clean Air Act. Some scholars feel that it is possible to seek action if groups of plant sources are identifiable. However, the matter has not been litigated definitively, and no consensus exists within the legal community.[2]

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[2] The remainder of this chapter is drawn chiefly from Keenan, Ohio Basin Interstate Energy Options, and James A. McLaughlin, Legal and Institutional Aspects of Interstate Power Plant Development in the Ohio River Basin Energy Study Region (ORBES Phase II).

The critical question, then, is whether there is evidence to suggest that any strategy, beyond the use of strictly technical approaches at individual plant sites, could be successful in mitigating impacts from polluted air masses that travel long distances. For more than a decade, the exploration of such strategies has centered on possible multistate siting arrangements; national siting legislation was being considered by Congress as early as 1970. For both technical and political reasons, however, these proposals have not been accepted. Thus, at neither the national nor the interstate regional level are siting arrangements in place that address air quality problems.

EMISSION REDUCTIONS. However, on the basis of ORBES research, a cautious assessment can be made that air quality could be improved by a regionwide techno-organizational strategy that would determine expected emissions, site plants, and coordinate operations related to air pollutant emissions. One way to achieve emission reductions would be the adoption of more stringent environmental controls, as in the strict environmental control scenario, in which more stringent criteria for siting plants also were assumed.

Another way in which emission reductions might be achieved is by the implementation of least emissions dispatching. This day-to-day load management technique would put fossil-fueled generating units into service in the order of least sulfur dioxide emissions, rather than least cost. Least cost dispatching is the traditional utility practice, and only one company that uses least emissions dispatching, Southern California Edison, has been identified.[3] Of course, individual utility companies in the ORBES region could initiate least emissions dispatch at their respective plants. The effects would be greatest, however, if this option were implemented by the large systems that operate in the region. So far as is known, least emissions dispatch has not been practiced on an interutility or interstate basis. However, regional reliability councils might encourage an interutility, interstate approach, and state public service commissions could do likewise within their states.

The least emissions dispatch strategy illustrates the positive effect that a regionwide change in utility operations could have on air quality, even under conditions of high electrical energy growth. A regional body concerned with both utility siting and operations could weigh the advantages and disadvantages of approaches such as those taken in the various ORBES scenarios. For example, in the electrical export case, a regional body might recommend that the electricity exports should be produced by nuclear-fueled rather than coal-fired units, thus avoiding the air quality impacts identified.

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[3] Southern California Edison applies the least emissions dispatch strategy only to oxides of nitrogen emitted primarily from oil-fired plants.

REGIONAL LOADINGS. A regional siting mechanism alone could indeed reduce pollutant concentrations at local "hot spots," where these concentrations are highest and where PSD increments are not available to accommodate new sources. Also, local situations where two or more power plant plumes interact could be avoided. Siting alone, however, could not reduce total regional pollutant loadings. The total regional pollutant loading would not be affected by a regional siting mechanism. Coupled with regional siting, however, certain operational changes--such as least emissions dispatch and uniform or differential emission reductions--could reduce total regional loadings, thus also reducing extraregional impacts. Given the interdependency of emission reductions, siting, and operations, it appears that regional coordination would be required to reduce pollutant loadings and/or to reduce concentrations from long-range transboundary pollution in the region and beyond.

Recent focus has been provided to the long-range transport issue by the attention given it by the northeastern states, which because of prevailing wind patterns experience impacts from pollutant loadings transported from the ORBES region. Policymakers must determine whether these negative impacts are significant enough to justify the creation of regional air pollution control bodies. Again, any organizational arrangement devised either to decrease total regional emissions or to reduce pollution transported to downwind states would require regional coordination of certain aspects of power plant operations.

If policymakers at either the state or national levels should decide to consider such a mechanism, several critical air-oriented questions must be answered. For example, should such an entity be, in effect, a regional air quality control agency? If it were to function as an air quality control agency, should it deal only with operational aspects of power plant air pollution or should it extend to siting? Finally, should such a mechanism be considered for the ORBES region or a similar area centered in the Ohio River valley, or should it be part of a national arrangement? Given the present dynamic character of the ORBES region, any public discussion of these questions also would include other issues. For example, in addition to power plants, other energy-related facilities are being developed in the region, and consideration of power plant siting probably would trigger controversy over the desirability of including other energy facilities in any siting arrangement. These issues are discussed in section 12.2, below.

Specialists disagree as to the desirability of multistate strategies to mitigate negative long-range transboundary pollution transport impacts, but the matter cannot be avoided. This is due in part to the controversy over acidic deposition, or acid rain, brought into prominence by officials in northeastern states and Canada. EPA officials have been forced to acknowledge the sensitivity between ORBES states, with their heavy use of coal, and northeastern states; recently the EPA administrator has addressed the matter.

As discussed in detail later in this chapter, the administrator has indicated his preference for a "regional, multi-state approach" to begin the process of combating emissions that he believes are associated with acid deposition.[4] He has not elaborated on such an approach, but one must presume that he envisages a federal mechanism that would be administered by EPA or a similar agency. Although the acid rain phenomenon is not understood fully, it is clear that long-range transport plays an important role. Increasingly, the acid rain question is affecting consideration of organizational mechanisms designed to mitigate multistate transboundary air pollution problems in the broadest sense.

STATE AND UTILITY PARTICIPATION. If the dialogue regarding the suitability of new organizational approaches for dealing with long-range transboundary pollution transport is to be meaningful, it must include participation by the states and the electric utilities. Increased voluntary cooperation among utilities themselves and among state administrative officials might be a way to mitigate negative air quality impacts. One rationale for such cooperation is that procedural difficulties and delays might be avoided and thus that negative air quality impacts could be alleviated sooner. However, it may not be in the utility's self-interest to cooperate. The Patriot case provides an example. Despite the difficulties encountered, Indianapolis Power and Light was awarded a permit to construct the facility. (In that instance, of course, cooperation among relevant utilities and the states of Kentucky and Indiana would have addressed local transboundary pollution transport problems as opposed to long-range transboundary problems.)

Little agreement appears to exist as to whether it is realistic to expect electric utilities in different states to cooperate in activities aimed at the mitigation of negative transboundary air quality impacts. Much of the disagreement stems from lack of consensus on whether technology and existing "know how" would permit utilities to achieve such an objective jointly.

Suggested cooperative strategies can be divided into two categories: (1) operations and (2) siting. Least emissions dispatch is a prime example of the former; as discussed in the context of the high electrical energy growth case, it might reduce total regional emissions of sulfur dioxide. However, since not even one utility in the ORBES region has felt it to be sound policy to institute this system in its own system, it seems unlikely that, without strong incentives from government at some level, two or more utilities would voluntarily implement the practice across system and state lines. Also, some utility leaders have stated that the potential for this mitigation strategy has been exaggerated.

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[4] Douglas M. Costle, "A Law in Trouble?," remarks delivered at the annual meeting of the Air Pollution Control Association (Montreal, June 23, 1980).

With respect to siting, the ORBES conclusion that local transboundary impacts indeed could be reduced through interstate siting efforts already has been noted. Whether siting alone could mitigate long-range transboundary impacts significantly is doubtful. Even if the utilities were to launch voluntary cooperative siting efforts, it is not clear that they could make the necessary organizational arrangements, given existing orientations to states and service areas. On the other hand, the industry cooperates voluntarily in other functions. Much of this cooperation takes place through the National Electric Reliability Council (NERC) and nine regional reliability councils. Through these councils, the nation's major electric power systems collect and exchange information on such matters as load projections, generating resources, and interconnected network facilities.[5]

It might be possible for Congress to expand existing legislation to encourage utility coordination of power plant siting across state lines, similar to the way the reliability councils were created following the 1965 "blackout" in the Northeast. Over the past decade, bills introduced in the Congress, some obtaining considerable support, have called for extensive use of the councils and/or the electric utility industry in general to create plans for power plant siting.

If utilities in some combination of states were to agree among themselves on an arrangement for interstate and/or multistate siting of plants, a method still would be required for administrative and/or regulatory review of their decisions at both the federal and the state levels. It is difficult to envisage alternative paths for such review. Under existing structural arrangements, review by the Federal Energy Regulatory Commission and either state siting agencies or public service commissions probably would be required. Coordination among utilities in such a voluntary arrangement would be extremely difficult. If such coordination were achieved, consideration also might be given to the identification or even the acquisition of sites on a regional basis by some interstate entity. Suggestive is a practice initiated by the state of Maryland, which buys and "banks" future sites.

Cooperation among states themselves to mitigate negative transboundary pollution is another possibility, but few such initiatives have been taken. Only one major proposal in the ORBES region is known. In September 1976, the then-governor of Kentucky proposed to the governors of four other states bordering the Ohio River (all of the ORBES states except Pennsylvania) that they cooperate in the siting of power plants. However, the idea was not pursued.

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[5] Most of the electric utility service in the ORBES region is coordinated by two regional councils: the East Central Area Reliability Council (ECAR) and the Mid-America Interpool Network (MAIN). See Jan L. Saper and James P. Hartnett, eds., The Current Status of the Electric Utility Industry in the ORBES States (ORBES Phase II).

Officials of such state agencies as public service commissions, environmental protection departments, and energy units apparently communicate very little across state lines in regard to possible cooperation in power plant siting. In fact, it appears to be difficult for such officials to communicate on siting issues even within their own states, due to the complexities of such areas as operations and permit and licensing procedures associated with plant siting and construction.

Before interstate or multistate cooperation in the mitigation of transboundary air pollution impacts could occur, legislative leaders in the various states would have to perceive these impacts as major problems. In only one ORBES state, Ohio, has the legislature given its administrative leaders a clear mandate to seek cooperation with other states. A section of Ohio's power siting statute specifically provides for joint proceedings with other states and the federal government and for entering into interstate compacts or agreements. Ohio also is the only ORBES state that, by legislation, has fashioned a "one-stop" siting procedure through which one agency has the authority to resolve all issues involving the acceptability of an electrical generating facility site (Ohio Rev. Code Ann., sec. 4906.01 et seq.). The Ohio Power Siting Commission, the lead agency through which the process operates, is made up of chief executive officers of the relevant state agencies and also includes public and legislative membership. If the other ORBES states were to create similar commissions, a suitable vehicle would exist for interstate discussions on siting problems.

INTERSTATE COMPACTS. Another potential vehicle is the interstate compact. The U.S. Constitution declares that "no state shall, without the consent of Congress...enter into any Agreement or Compact with another State" (art. I, sec. 10). The courts have held, however, that such congressional consent is required only when states create an organization "tending to the increase of political power in the states, which may encroach upon or interfere with the just supremacy of the United States" (Virginia v. Tennessee, 148 U.S. 503 (1893)). Given the current concern over energy developments, the courts might hold that congressional approval would be required of any new interstate agreement designed to mitigate transboundary air impacts.

Ohio River Valley Water Sanitation Commission. Although in recent years interest has increased in the use of interstate compacts as a possible mechanism to mitigate air-related impacts, no serious attention has been given to such an approach in any ORBES state legislature. However, state commissioners of an organization established 22 years ago through an interstate compact to improve water quality in the Ohio River valley have expressed considerable interest in transboundary air problems. This organization is the Ohio River Valley Water Sanitation Commission (ORSANCO), formed when governors of the six ORBES states, plus New York and Virginia, signed an interstate compact. Since early 1979, the possible role of ORSANCO in the development of a multistate siting entity has been under discussion by commission members.[6] Beyond supporting an exploratory study on whether there is need for a new or existing organization to engage in siting activities, the ORSANCO commission has made no formal recommendation on the establishment of such a body.

Some members of ORSANCO panels believe that the group's compact could be modified to permit supplementary agreements, between as few as two member states, to resolve transboundary air pollution conflicts and other problems relating to interstate facility siting. Under such an agreement, the concept of "advance consent" might be exercised, thus avoiding the need to obtain congressional approval of each agreement between states. ORSANCO commissioners who favor such an expansion of the organization's role have emphasized that a change need not interfere with siting-related steps, particularly the issuance of construction and operating permits, that now are performed by state or federal agencies. Rather, the goal would be to identify both prime siting areas and those unacceptable on the basis of multistate and regional criteria. As a proposal from one former commissioner stated it, an ORSANCO-based arrangement could be "applicable to the entire river valley or portions thereof adjacent to two or more states. At the very least, a permit coordination, or perhaps a multistate certification process, could be devised even if nothing more profound were done."[7]

A number of advantages and disadvantages can be cited in regard to ORSANCO's role in mitigating negative air quality impacts. A major advantage is that ORSANCO is an entity already in place, and it would take years to approve a separate interstate body. However, ORSANCO is a water-related organization, while air quality probably will be the major controlling factor in operational and siting problems. Moreover, although the agency has qualified staff to carry out its present functions, the staff is limited in their air-related capabilities. Another advantage is that eight key states are commission members; nevertheless, the commission includes neither

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[6] See memorandum from Kentucky Commissioner Eugene F. Mooney, chairman, Task Force on Major Facility Siting, to ORSANCO members (January 10, 1979), and Eugene F. Mooney, Proposal to ORSANCO on Major Facilities Siting Process for Ohio River, distributed as Appendix G, at ORSANCO commission meeting (September 14, 1978).

[7] Mooney, Proposal to ORSANCO.

Tennessee nor other states in the broader Ohio Basin. A third advantage is the broad base of the long-time ORSANCO constituency, which consists of the eight member states; industry, including the electric utilities; and municipalities. However, "newer" concerns, such as environmental groups that focus on coal-related air quality problems, perceive limited access to the body. Finally, ORSANCO is experienced in political affairs and interstate diplomacy and probably is capable of articulating the states' position in conflicts with the federal government.

Delaware River Basin Compact. No interstate compact to mitigate transboundary air pollution is known to operate anywhere in the country at this time. However, the Delaware River Basin Compact has organizational elements that could be relevant in the consideration of such mechanisms for the ORBES region. The organization "has played an active role in electric energy facility siting and has been instrumental in both assisting and obtaining overall approval of sites and in discouraging the utility from mis-siting projects."[8] An agency established by the compact has the authority to manage the water resources of the river basin without regard to political boundaries. Generating facilities on the Delaware River were threatening to seriously affect the water quantity and quality of basin streams at low flow. Therefore, in 1971, the Delaware commission amended its rules to require that utilities obtain approval of water use for projects with generating capacities of 100 megawatts electric or more. Although water issues were the impetus for the creation of the Delaware Compact Commission, while air quality problems are viewed as most critical in the ORBES region, the tools utilized in interstate administration of the use of water resources might suggest organizational techniques for regional management of air quality problems.

TENNESSEE VALLEY AUTHORITY. In considering strategies to mitigate negative air quality impacts in the ORBES region, it is difficult to ignore the Tennessee Valley Authority, a federal corporation created in 1933 and a major consumer of coal among the nation's utilities. The TVA service area includes parts or all of seven states: Virginia, North Carolina, Kentucky, Tennessee, Mississippi, Alabama, and Georgia. Of these states, only Kentucky also is in the ORBES region. However, in terms of overlapping problems of long-range transboundary air pollution transport, the two regions are so interconnected as to make separate treatment almost impossible. Vital connections also are evident in at least four other areas: (1) relationships and comparisons between TVA- and ORBES-region utilities in providing coal-generated electricity to uranium enrichment facilities, (2) ongoing comparisons of different rate structures between TVA and ORBES-region utilities, (3) competition among coal suppliers in obtaining contracts with ORBES-region utilities and TVA, and (4) linkages between the two regions in waterway management. Thus, it is necessary to ask whether any strategy in the ORBES region--operational or siting-oriented--could be effective without the inclusion of the six other states that, together with Kentucky, form the TVA service area.

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[8] Herbert A. Howlett, "The Role of River Basin Commissions in Energy Facility Siting," paper delivered at a seminar of the Southern Governors' Conference (March 25, 1977).

Even casual consideration of operational and/or siting cooperation between the ORBES and TVA areas for purposes of mitigating air impacts probably would result in emotional responses from utility leadership in both regions. Intense ideological differences separated the early supporters of the TVA idea from the leaders of the investor-owned utilities. Although this conflict has diminished somewhat over the years and TVA and ORBES-region utilities work together in such areas as electric power reliability, cooperation would be difficult to implement. However, given the increasing importance of the TVA region and the ORBES region in eastern U.S. air quality management, pressures might force some form of cooperation among TVA, the investor-owned utilities in the ORBES region, and other, smaller generating entities such as the rural electric cooperatives and the municipalities that produce electricity.

OHIO RIVER BASIN COMMISSION. For different reasons, then, both ORSANCO and TVA will be important in discussions of multistate air quality management in the ORBES region. Probably of less significance are a number of other regional organizations. One of these groups apparently shares with ORSANCO an interest in providing counsel on the interstate siting of power plants. This is the Ohio River Basin Commission (ORBC), a federal-state partnership composed of 11 Ohio River Basin states (including the 6 ORBES states), 9 federal agencies, and ORSANCO. ORBC was created in 1971 under Title II of the Water Resources Planning Act of 1965 (42 U.S.C. 1962). Commission spokespersons have noted that the organization may be suitable for studying siting dilemmas and possibly becoming involved in giving counsel or making decisions. In developing its budget in recent years, the ORBC staff has acknowledged power plant siting problems, including transboundary air transport, and has sought funds to study associated interstate issues.

A negative factor in considering ORBC for a possible role in air quality impact mitigation is its basic organizational mission, which is limited to planning focused on water problems. However, the argument has been made that, in the absence of other effective organizations, the basin commission is an appropriate institution to participate in planning for future air quality management. Most of the disadvantages noted above in connection with ORSANCO's possible role in air quality affairs apply to ORBC, perhaps in a more telling fashion. In addition, leaders in certain of the states holding commission membership have been dissatisfied with the organization's activities. In the late 1970s, Ohio withdrew its financial support, charging that the state had derived little benefit from ORBC membership.

APPALACHIAN REGIONAL COMMISSION. A 13-state economic development-oriented organization centered in Appalachia is so tied to a continued emphasis on coal that it must be mentioned in the context of air quality concerns. This body is the Appalachian Regional Commission (ARC). It was created by Congress in 1965 under the Public Works and Economic Development Act of 1965 (42 U.S.C. 3121) for the purpose of promoting Appalachian economic development. The ARC region includes all of West Virginia; portions of three other ORBES states, Pennsylvania, Kentucky, and Ohio; and parts or all of nine other states. Because of the overlap between much of the ARC region and the TVA service area, many of the comments above in regard to TVA and the ORBES region air quality relationships apply equally to the interface between the ORBES region and the ARC area. A proposal has been made that ARC's functions be expanded so that it could address transboundary impacts in the Ohio River valley and perhaps become an energy facility siting body. This also would involve an expansion of the commission's region. However, the proposal finds little support in Indiana, Illinois, and Ohio, where many disagree with the ARC's policies on economic growth.

FEDERAL ACTIONS. Most federal initiatives probably will center on the Clean Air Act. Since the 1977 amendments were signed, various interests with a variety of perspectives have sought radical changes in the act. Often electric utility representatives describe it as unnecessarily complex and excessively time consuming. On the other hand, environmentalists and some EPA officials characterize the Clean Air Act as ineffective in addressing troublesome problems, including multistate, long-range transboundary air pollution transport.

In August 1981, current authorization measures to fund the administration of the Clean Air Act will expire. This means, in effect, that Congress soon will be reviewing the 1977 amendments. The EPA administrator has stated that the act "could be gutted if people don't pay attention to what is happening." He has emphasized the problem of acidic deposition, which involves "numerous jurisdictions, existing sources, and energy issues," noting that "the Clean Air Act's primary reliance on the States is sound, but on this issue we confront one of its principal shortcomings: how to deal effectively with regional and area-wide problems involving transport over long distances, and across state and national boundaries." Moreover, he has questioned seriously "whether the State Implementation Plan process--requiring as it does a State-by-State, plant-by-plant approach--is the best way to solve this problem in a timely fashion. I would personally prefer a regional, multi-state approach to the problem of total loadings--one which would, for example, allow an entire utility system to find the most cost-effective approach to getting a percentage reduction from among a mix of all their loadings; such a system should even be flexible enough to permit trade-offs with other utility networks. This would require a change in the law."[9] Thus, it appears likely that any new national initiatives aimed at the mitigation of transboundary air pollution impacts will focus mainly, perhaps exclusively, on mechanisms to combat the acidic deposition phenomenon.

To emphasize points made above, a mechanism capable of addressing rather well-understood impacts might be far different from one that focuses on little-understood long-range, multistate transboundary problems. The policy debate that will take place in the upcoming Clean Air Act review will include at least three distinct points of view. The first argument, whose proponents will include many leaders from the ORBES coal-producing states, is that present energy needs and associated national security matters are so serious that additional attention cannot be paid to questions of transboundary air pollution. The second argument, made by many northeastern groups, probably will call for new organizational mechanisms to combat long-range multistate transboundary pollution transport at almost any cost. Power plants in ORBES states seem certain to be among the targets. A possible third argument might be made by a coalition of ideological opponents of further federal action, particularly in the form of regional approaches, and some environmentally conscious individuals. These environmentalists, though concerned over long-range transboundary pollution transport, might well question the possibilities for success of any multistate strategy and might fear that such an emphasis would turn attention from better-understood local impacts.

Finally, it should be noted that arguments for more aggressive federal action in mitigating air quality impacts, perhaps even federal preemption, will continue.

12.2 Possible Influences

The analysis of the five ORBES coal-dominated scenarios reveals that air quality problems probably will present the most serious challenges through the year 2000, even with the reductions in pollutant emissions projected under the scenarios. However, air quality alone may not be the impetus for policy changes to ameliorate these negative impacts. Among the other possible factors are the U.S.-Canadian discussions on acid rain, nuclear fuel use, synthetic fuels, and energy mobilization.

U.S.-CANADIAN DIALOGUE. At any time, the ongoing dialogue between Canada and the United States over air pollution transport across their common border could trigger unexpected developments in the ORBES region. If the Canadian position should become particularly aggressive, the problem of long-range transboundary pollution transport from the ORBES region suddenly could become an international problem in need of national attention. Thus, any multistate mechanism designed to address the problem would be likely to assume first-line management responsibility.

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[9] Costle, "A Law in Trouble?"

NUCLEAR ENERGY. Action at one or more levels of government could be stimulated by developments other than coal-related impacts. In turn, this action could set in motion broader strategies affecting the total energy sector--including coal-fired facilities in the ORBES region. The present uncertainty with respect to the use of nuclear energy for electrical generation is a case in point. A nuclear fuel substitution scenario is discussed in chapter 14, and policy questions relating to nuclear facilities are discussed in chapter 15. However, these chapters do not deal with the possibility that concern over nuclear power also could stimulate consideration of the impacts of coal-fired plants. In fact, many such deliberations have occurred in recent years at both the national and the regional levels. Often they conclude that a plan for power plant siting and operations could not be effective if it is designed to deal with only one type of fuel use. If interstate or multistate mechanisms were to be used in the siting and operation of nuclear-fueled generating facilities, they also might be used for other installations associated with the broad nuclear fuel cycle, including nuclear weapons facilities, uranium mines, uranium enrichment facilities, and waste disposal sites.

Thus, discussions of interstate or multistate siting mechanisms for coal-fired electrical generating facilities often cannot be separated from consideration of nuclear-fueled generating facilities or other nuclear installations. And the complexity does not end there. Given the national policy for reducing our dependence on foreign oil, regional or national proposals for energy facility siting increasingly have included consideration of a number of types of installations in addition to electrical generating plants.

SYNTHETIC FUEL PLANTS. Relevant here is the renewed emphasis on coal-based synthetic fuel plants, using both gasification and liquefaction processes, which now are being planned in the ORBES region. Such plants are not projected in the ORBES scenarios, chiefly because these installations are not expected to be a significant energy source by the year 2000 in the study region.

In July 1980, the President signed a bill that allocates $20 billion to spur the production of synthetic fuels to replace foreign oil. The legislation sets a goal of synthetic fuel production equivalent to 500,000 barrels of oil a day by 1987 and 2 million barrels a day by 1992. To put this goal in perspective, for the four-week period ending September 5, 1980, gross imports of crude oil and petroleum products together averaged 5.7 million barrels a day, which is 33.2 percent less than the average for a comparable period in 1979.[10]

In practical terms, policymakers will likely be faced with the task of assessing the possible interaction of the impacts from new synthetic fuel plants with certain of the impacts from power plants identified in the ORBES analysis. Synthetic fuel plants probably would not have major negative effects on air quality and would not be expected to consume more water than coal-fired generating plants of comparable size.[11] However, any case being made for future interstate, multistate, or national power plant siting and operation mechanisms probably will consider the incorporation of synthetic fuel installations.

COAL TRANSPORTATION. The success of the nation in using larger amounts of coal in order to reduce its dependence on foreign oil will rest in part on the response capability of various coal transportation modes: railroads, waterways, highways, and pipelines (for slurry). Many of the transport problems to be faced are intrastate in nature. Solutions to most of the intrastate problems will be built on long legal and institutional histories. However, the possible need to expand existing river ports or to construct new port facilities is one interstate aspect of coal transport that presents new challenges. Protracted conflict between states over major riverport and coal terminal sites on the Ohio River conceivably could bring pressure for such installations to be included in any proposal for an interstate facility siting and operation mechanism.

ENERGY MOBILIZATION. The unpredictable factors discussed above relate to possible multistate or international action designed to mitigate air quality impacts. However, unexpected events also could trigger the relaxation of such efforts. For example, Congress could decide that the need to develop energy facilities is so overriding that a mobilization posture is required. The President's 1979 proposal for a national Energy Mobilization Board (EMB), stalled in Congress in late June 1980, assumes such a need for energy development. The EMB proposed by the President would have exercised sweeping powers to expedite energy projects, including the lowering of environmental standards for certain energy projects. If the President's proposed EMB or similar legislation is passed, this would indicate a climate in which multistate action to mitigate negative air quality impacts might not be taken.

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[10] U.S. Department of Energy, Energy Information Administration, Weekly Petroleum Status Report (DOE/EIA-0208 (80-37), September 12, 1980).

[11] U.S. Department of Energy and U.S. Environmental Protection Agency, Energy/Environment Fact Book (EPA-600/9-77-041, March 1978).

12.3 Underlying Questions

This chapter indicates that air quality probably is the most crucial factor in the use of coal for electrical generation in the ORBES region. Many technology-oriented strategies to mitigate negative air quality impacts from coal use for electrical generation are in various stages of operation, experimentation, and study. An array of organizational approaches could encourage cooperation among the ORBES states in reducing negative impacts. Also, however, new national legislation to stimulate construction of coal facilities other than power plants might render obsolete certain aspects of proposed multistate mechanisms aimed primarily at air pollution from coal-fired electrical generating facilities.

Three basic questions must be answered from both the regional and the national perspectives: (1) Would any organizational change under consideration make it less difficult to mitigate negative impacts from burning coal? (2) Would such a change enable the United States to reduce its dependence on foreign oil? (3) Would the change be consistent with the essential democratic values of our society?

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Errata

page 12, line 10 change "figure ES-5" to "figure ES-4".

page 13, line 2, change "figure ES-6" to "figure ES-4".

page 14, line 5, change "figure ES-5" to "figure ES-6".

page 14, line 7, change "figure ES-6" to "figure ES-5".

page 165, in the paragraph labelled *Monetary Crop Losses*, line 5, change "$95 million" to "$95 billion".

FUEL SUBSTITUTION AND CONSERVATION EFFECTS

It appears extremely unlikely that, before the year 2000, regulatory factors and other conditions will result in substantial changes in patterns of fuel use for electrical generation in the Ohio River Basin Energy Study (ORBES) region. Reflecting regional conditions, this report has stressed the use of coal. However, policymakers must be aware of the institutional barriers and opportunities associated with partial substitution of other fuels for coal, as well as the barriers and opportunities associated with a major regional emphasis on energy conservation.

This portion of the report considers the effects of four hypothetical futures that would mean less emphasis on the use of coal for electrical generation in the ORBES region. The first three scenarios call for fuel substitutions for coal-fired electrical generation: (1) an increase wherever possible in the use of natural gas for applications other than central station electrical generation (the natural gas substitution case), (2) an increase in nuclear-fueled electrical generation, and (3) an emphasis on alternative fuels, such as solar energy. The final scenario calls for a regional emphasis on conservation. These four scenarios are described in chapter 13.

Even under any of the futures discussed here, however, the ORBES region still would be dominated by the use of coal for electrical generation. Thus, policymakers still would have to deal with the impacts on air quality associated with coal emphasis.

In contrast to the extensive impact analysis carried out for the coal-dominated futures (chapters 6 through 11), impact analysis of the fuel substitution and conservation scenarios is relatively limited. Thus, the impacts of the four cases are contrasted with each other and with the coal-dominated base case in one chapter, chapter 14. In general, the same impact areas are considered as for the coal-dominated futures: air, land, water, employment, and health.

As indicated above, institutional barriers and opportunities associated with the partial replacement of coal by other fuels and by conservation measures are of chief interest here. These barriers can be assessed with varying degrees of certainty. In the case of natural gas substitution, it need only be noted that over many years an institutional system has been developed for the production, transmission, and distribution of this fuel. Therefore, no major institutional changes probably would be required, and institutional considerations related to an expanded use of natural gas are not dealt with. If nuclear-generated electricity were to replace a substantial portion of the electricity generated by coal--a highly improbable circumstance--an extensive though controversial literature on institutional considerations is available; this literature is reviewed briefly. With regard to alternative fuels and conservation, however, institutional barriers or opportunities must be discussed in a more general way, even though significant regional problems could be present. This is due not only to the focus of ORBES on electrical generation, but also to the relatively late entry that these measures would have during the study period, which makes the analysis less certain. Institutional factors relating to implementation of the nuclear substitution, alternative fuel substitution, and conservation scenarios are treated in chapter 15.

13. Descriptions of the Fuel Substitution and Conservation Scenarios

The four scenarios discussed in this portion of the report reflect assumptions about energy and fuel use characteristics that differ from those of the coal-dominated futures (see chapter 5). Three of these scenarios assume somewhat less emphasis on coal use for electrical generation because of partial substitution by other fuels. In the natural gas substitution case, natural gas is substituted for other fuels whenever practicable, except to fire utility boilers. In the nuclear substitution case, nuclear-fueled electrical generating capacity substitutes directly for coal-fired capacity. In the alternative fuel substitution case, a variety of alternative fuels, including biomass and solar energy, partially replace coal-fired capacity. The fourth case assumes that, because of the implementation of conservation measures, energy growth in the ORBES region is significantly less than under all other scenarios. As shown in figure 13-1, all four cases are compared directly with the coal-dominated base case; comparisons also are made among the fuel substitution and conservation scenarios themselves.

SOCIAL VALUES. The social values implicit in the nuclear and natural gas substitution scenarios parallel those associated with the coal-dominated futures. In addition, under nuclear substitution, a strong belief in science as a means to achieve advancement is implicit. The additional values implicit in the alternative fuel substitution case are individualism, science, and conservation/preservation; in the conservation case, efficiency and conservation/preservation.[1]

POPULATION GROWTH, ECONOMIC GROWTH, AND ENVIRONMENTAL STANDARDS. The same regional population growth rate as in the coal-dominated futures (15 percent over the period 1970 to 2000) is assumed in the four fuel substitution and conservation scenarios. Likewise, regional economic growth is assumed to average 2.47 percent annually in all cases. Base case environmental controls also are assumed for all four scenarios.

ENERGY AND FUEL USE. There is great variation, however, in the energy and fuel use characteristics that define the fuel substitution and conservation

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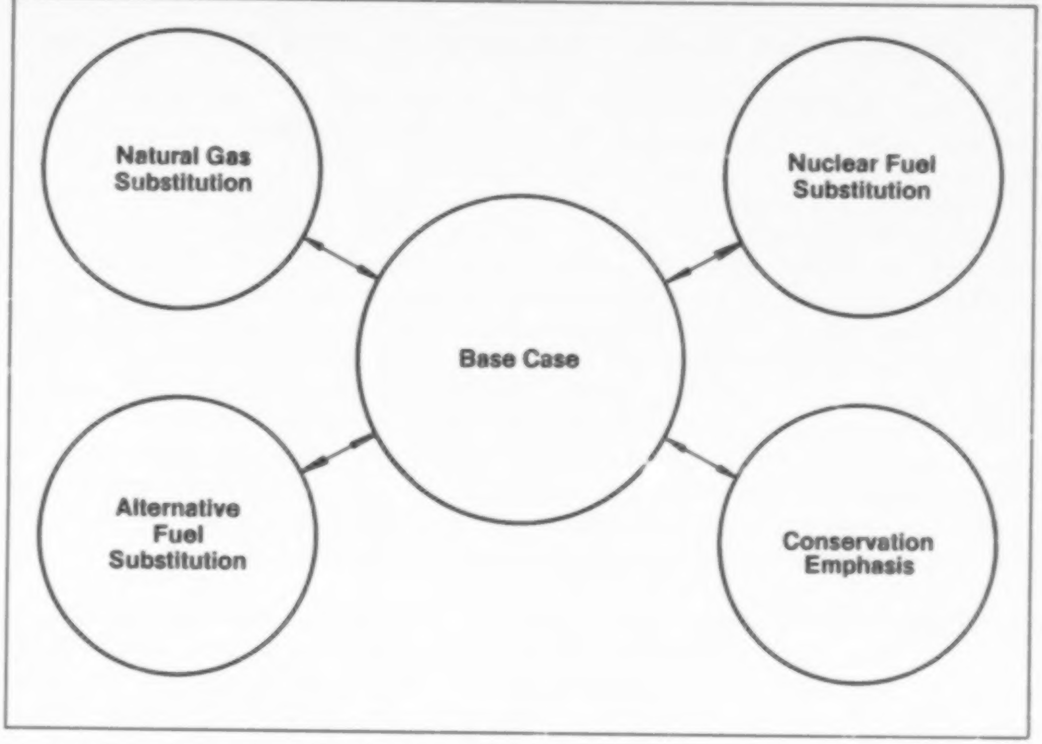
[1] See Harry R. Potter and Heather Norville, Ohio River Basin Energy Study: Social Values and Energy Policy (ORBES Phase II).

Figure 13-1
Major Variables and Comparisons
Base Case, Fuel Substitution Scenarios, and Conservation Scenario


Natural Gas Substitution
Nuclear Fuel Substitution
Base Case
Alternative Fuel Substitution
Conservation Emphasis

scenarios.[2] Growth rates for the various sectors appear in table 13-1, which includes base case rates as well as those for the four cases under discussion. In the natural gas substitution case, natural gas supplies 57 percent of the heat required for industrial processes in 1985 and 85 percent in 2000, compared with 37 percent and 10 percent, respectively, under the base case. This difference is reflected in significantly lower rates of electricity demand growth and coal growth and a significantly higher rate of natural gas

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[2] See Walter P. Page, Doug Gilmore, and Geoffrey Hewings, An Energy and Fuel Demand Model for the Ohio River Basin Energy Study Region (ORBES Phase II).

Table 13-1
Growth Rates and Installed Capacity, Base Case, Fuel Substitution Scenarios, and Conservation Emphasis Scenario (1974–2000), Annual Averages

Scenario	Economic Growth	Electricity Growth	Coal Growth	Natural Gas Growth	Refined Petroleum Growth	Energy Growth	Installed Capacity Year 2000 (MWe)
Base Case	2.47%	3.13%	2.40%	−0.40%	0.37%	1.49%	153,245
Natural Gas Substitution	2.47%	2.00%	0.74%	3.55%	0.51%	1.61%	113,595
Nuclear Substitution	2.47%	3.11%	1.52%	−0.40%	0.37%	1.50%	145,295
Alternative Fuel Substitution	2.47%	2.69%	1.73%	−1.20%	0.15%	0.95%	134,295
Conservation	2.47%	0.90%	0.20%	−0.31%	−0.54%	0.10%	104,495

growth. With nuclear substitution, however, energy and fuel use characteristics are about the same as in the base case, except for a reduction in the use of coal corresponding to the replacement of coal-fired by nuclear-fueled electrical generating capacity under this scenario. On the other hand, under the alternative fuel substitution case, growth in conventional energy sectors is much lower than under the base case and all other scenarios except the conservation emphasis case. This lower growth occurs because of limitations placed on end uses of the fuels emphasized in the other ORBES scenarios. Natural gas experiences an especially sharp decline under alternative fuel substitution. Among all the ORBES scenarios, the conservation emphasis case results in the smallest overall energy growth rate, which is reflected in all sectors. For example, the demand for electricity under the conservation case grows at an annual average rate of 0.90 percent annually, compared with 3.13 percent under the base case.[3]

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[3] The major assumptions of the alternative fuel substitution case concerning the replacement of coal-fired capacity in the region with less conventional fuels were implemented by prorating national data reported in the Technology Assessment of Solar Energy (TASE) to the ORBES region. See Y.M.

COAL SUPPLY. The same assumptions about the location and sulfur content of coal to supply scenario demands are made under the fuel substitution and the conservation scenarios as were made under the coal-dominated futures. Although the absolute tonnages of coal arising from different Bureau of Mines districts are lower in all these cases than under the base case, the percentages remain the same across scenarios.[4]

SITING. The same method of projecting the generating unit additions needed to meet electricity demand was used for both the coal-dominated scenarios and the fuel substitution and conservation scenarios.[5] In general, the base case pattern was followed for the fuel substitution and conservation cases, with subtractions as necessary. (See figure 5-4 for a depiction of the regional coal-fired generating capacity under the base case in the year 2000.) However, under the two scenarios that call for the fewest coal-fired additions--natural gas substitution and conservation emphasis--the relatively few additions are located in those counties that, according to base case environmental controls, are the most suitable. The siting pattern for coal-fired generating capacity under the conservation emphasis scenario in the year 2000 is shown in figure 13-2. As implied above, the conservation case calls for the fewest capacity additions between 1986 and 2000 among all the ORBES scenarios.

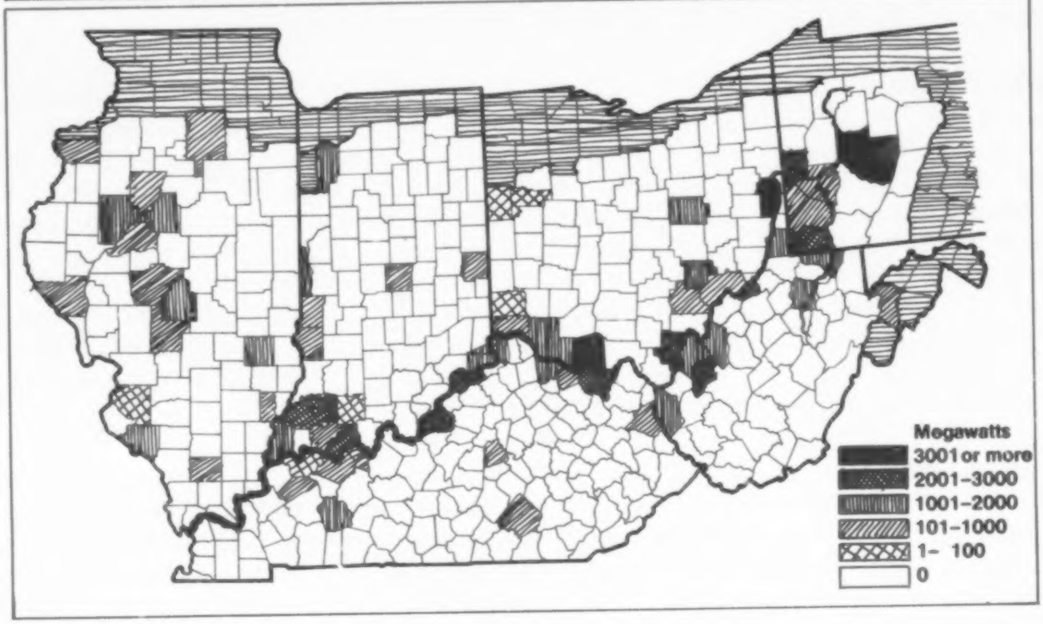
In both the conservation emphasis scenario and the natural gas substitution scenario, the on-line dates of selected capacity additions planned by the utilities are delayed to permit an approximately equal annual increment of additions over the study period, as in all the other scenarios.

Shiffman, TASE Project: DPR Data Base and Maximum Practical Solar Case Disaggregations (MITRE, WP-79W-00110, 1979), and Technology Assessment of Solar Energy: Description of Solar Technology and Energy Scenarios (MITRE, WP-79W-0028, vols. II and III, 1979); Page, Gilmore, and Hewings, An Energy and Fuel Demand Model; and Walter P. Page and John Gowdy, Gross Regional Product in the Ohio River Basin Energy Study Region, 1960-1975 (ORBES Phase II).

[4] See Donald A. Blome, Coal Mine Siting for the Ohio River Basin Energy Study (ORBES Phase II), and Walter P. Page, An Economic Analysis of Coal Supply in the Ohio River Basin Energy Study Region (ORBES Phase II).

[5] See Steven D. Jansen, Electrical Generating Unit Inventory, 1976-1986: Illinois, Indiana, Kentucky, Ohio, Pennsylvania, and West Virginia (ORBES Phase II); Gary L. Fowler et al., The Ohio River Basin Energy Facility Siting Model: Methodology (ORBES Phase II); and Gary L. Fowler et al., The Ohio River Basin Energy Facility Siting Model: Sites and On-Line Dates (ORBES Phase II).

Figure 13-2
Coal-Fired Electrical Generating Capacity, ORBES Region, Conservation Emphasis Scenario, Year 2000



If some planned additions were not rescheduled under this overall low growth rate in regional electrical generating capacity, there would be negative growth rates in capacity between 1985 and 2000. Finally, a 35-year generating unit lifetime is assumed for the three fuel substitution scenarios and the conservation emphasis scenario.

Under the nuclear substitution case, regional generating unit additions after 1985 are both nuclear fueled and coal fired. The nuclear substitution case is the only scenario in which nuclear-fueled capacity additions are sited. Distribution of the nuclear-fueled units is based on three major factors. First, the current practice of locating only coal-fired capacity in Kentucky and West Virginia is assumed to continue, and thus no nuclear-fueled units are sited in those states. Second, scenario unit additions in other state subregions are allocated with preference to counties where utilities have announced nuclear-fueled plants whose capacity can be expanded or to counties where such plants already are in operation. Third, nuclear-fueled scenario unit additions are allocated to counties independent of the location of planned or scenario-designated coal-fired generating capacity.[6]

The number of scenario unit additions for the fuel substitution cases and the conservation case appear in table 13-2. For purposes of comparison, table 13-2 also includes the number of additions for the base case.

SOLAR ENERGY PROCESSES. In the year 2000 under the alternative fuel substitution scenario, energy from direct and indirect solar energy processes is assumed to account for almost 11 percent of utility-owned energy production in the ORBES region. These processes consist of a variety of solar energy technologies, wind, and biomass. In addition, dispersed generation of electricity by means of wind would supply 0.6 percent of electricity demand. Heat for industrial processes from solar energy and from biomass would account for 16 percent of process heat requirements. Seventeen percent of space heating requirements would be supplied by biomass in the form of wood and by active and passive solar systems, while 33 percent of water heating requirements would be supplied by solar energy.[7]

Direct Solar Energy Conversion. The four basic types of direct solar energy conversion systems are (1) passive and hybrid solar energy heating and cooling systems, (2) active solar heating and cooling systems, (3) photovoltaic energy systems, and (4) solar thermal power systems.[8] Passive and hybrid solar heating and cooling systems rely primarily on building designs and components that transfer energy into, out of, and within the building through the natural processes of conduction, convection, and radiation. Mechanical equipment, such as fans, pumps, or compressors, plays a minimal role in passive solar except when this equipment can be used effectively to augment the natural energy flows or when capital costs and operating energy are justified by improved system performance. When another solar technology is integrated into a passive solar building, it is considered a hybrid solar application.

Passive cooling systems discharge unwanted heat through natural means. The sky, atmosphere, ground, and water are potential heat sinks for these

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[6] The siting patterns for the nuclear fuel substitution scenario, the natural gas substitution scenario, the alternative fuel substitution scenario, and the conservation emphasis scenario appear in Fowler et al., The Ohio River Basin Energy Facility Siting Model (vol. II).

[7] Page, Gilmore, and Hewings, An Energy and Fuel Demand Model.

[8] Descriptions of these technologies are taken from U.S. Department of Energy, Solar Energy Program Summary Document: FY 1981. See also Vincent P. Cardi, Larry Harless, and Thomas Sweet, Legal and Institutional Issues in the Ohio River Basin Energy Study (ORBES Phase II).

Table 13-2
Coal-Fired and Nuclear-Fueled Capacity Additions, ORBES Region: Base Case, Fuel Substitution Scenarios, and Conservation Emphasis Scenario, 1986–2000

	Number of Scenario Unit Additions					
ORBES State Portion	Base Case	Natural Gas Substitution	Nuclear Substitution		Alternative Fuel Substitution	Conservation Emphasis
	coal	coal	coal	nuclear	coal	coal
Illinois	13	4	4	19	9	2
Indiana	18	7	6	7	13	4
Kentucky	16	5	4	0	11	2
Ohio	20	8	8	2	14	6
Pennsylvania	14	4	4	5	9	2
West Virginia	14	6	6	0	10	4
Total Units	95	34	32	33	66	20

Note: Standard coal-fired capacity additions are 650 megawatts electric per unit. Standard nuclear-fueled capacity additions are 1000 megawatts electric per unit. Included in the figures are units scheduled by the utilities through 2000; these units are of varying megawattage.

systems. All new buildings can benefit from passive heat and cooling design concepts, but often it is not cost effective to retrofit existing buildings for passive solar systems.

Active solar heating and cooling systems use modular or site-built collection systems (predominantly flat plate collectors) to convert insolation into thermal energy by absorbing radiation. Mechanical subsystems transfer the heat into the building by means of air or liquids, and the heat then either is used directly to heat space or water or is stored for later use. Swimming pool heating, domestic hot water heating, and space heating are the leading applications in present use. Solar cooling technology provides for more economical year-round employment of solar collection systems.

The third category of direct solar energy conversion systems, photovoltaic systems, provide a clean, simple method for the direct conversion of sunlight to electrical energy. First developed for use in the space program, photovoltaic solar cells absorb sunlight and convert it directly into electricity. Because photovoltaic systems are intrinsically modular, a wide range of system sizes and models can be designed to fit almost any need. The systems can be used either in central stations in which power is generated for sale to customers or in distributed applications in which the customers produce the power themselves. Two major markets for photovoltaic power systems are (1) grid-connected applications and (2) stand-alone or off-grid applications (such as remote telephone relay stations). The principal grid-connected applications are considered to be residential (5 to 20 kilowatts), community and intermediate load center (50 to 2000 kilowatts), and central station (over 20 megawatts).

In the final category, solar thermal power systems, the sun's heat is concentrated and used to heat water or some other fluid to provide industrial process heat or to drive a turbogenerator. The primary objective is to provide an alternative to fossil fuels for industrial and utility applications. Applications that provide both heat and electricity, called "total energy systems," also are included. The high-temperature heat from solar thermal systems can be used directly in industrial processes, in turbines to produce electricity, in cogeneration, and ultimately to produce liquid and gaseous fuels. Moreover, in low-temperature applications, concentrating collectors are expected to compete strongly with flat-plate collectors, which already are commercial.

Wind Energy. Wind energy conversion systems (WECS) provide another promising way to tap the sun's energy. A small portion of the solar energy received by the earth, about 2 percent, is converted naturally into surface winds as a result of the uneven heating of the atmosphere. Natural forces tend to concentrate this resource so that a reasonably windy site has about the same annual energy available per square foot of collector as does a good solar insolation site.[9] Under a conservative estimate, the total wind energy available over the land area of the United States, calculated at 115 billion megawatt hours, has the potential of generating 1 billion megawatt hours of electricity annually, or about 20 percent of the amount of electricity generated each year in the United States.

WECS usually are classified as horizontal- or vertical-axis machines. A typical horizontal-axis machine has the classic windmill blades; it swings, or yaws, to follow changes in wind direction. One vertical-axis machine under development is the Darrieus ("eggbeater") type, with blades that catch wind from any direction. The main components of both types of machines are their rotor blades, gear trains, electric generators, structures, and towers. The principal engineering challenge is to design wind machines that can be manufactured cheaply, can perform reliably, and can capture a significant fraction of available energy. The principal applications of WECS are for mechanical water pumping and electric power generation, although heating, cooling, and other applications also are practicable. Small-scale systems (1 to 100 kilowatts) can be employed on-site for residential and farm uses; intermediate-scale systems (100 to 1000 kilowatts), for larger farms, irrigation, small utilities, and remote communities; and large-scale systems (over 1 megawatt), for electric utility and industrial uses.

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[9] Information on wind energy conversion systems is drawn from U.S. Department of Energy, Solar Energy Program Summary Document: FY 1981, and D.A. Wiederecht, Small Wind Energy Systems: Their Application and Testing (Rocky Flats, February 1977). See also Cardi, Harless, and Sweet, Legal and Institutional Issues.

Biomass. The final broad class of alternative energy processes that would substitute for coal is biomass, which means the products of photosynthesis (such as grasses, wood, and agricultural crops and their residues) and other biological products (such as animal waste) that can be energy sources. Although their origins are not entirely biological, other waste materials (such as municipal solid waste and food-processing wastes) often are considered in discussions of bioenergy.[10]

Biomass energy sources are extremely versatile. Wood and other lignocellulosic materials (such as crop residues and grass and legume herbage) can produce heat, steam, or electricity when burned directly in large boilers or in small units such as wood stoves. These materials also can be used to produce alcohol and other liquid fuels. Municipal solid waste has the same applications but, like animal waste, also can be gasified in anaerobic digesters to produce methane, the primary component of natural gas. Starch and sugar crops (including corn, wheat, oats, sugarcane, sugarbeets, and grain and sweet sorghum), as well as many food-processing wastes, are used to produce ethanol, the alcohol component of gasohol.

CONSERVATION. In the conservation emphasis case, two major factors account for the extremely low energy growth rate projected for that scenario. First, it is assumed that the maximum practicable end use efficiencies would be achieved for all energy uses. In the industrial and commercial sectors, an energy efficiency increase is defined as a reduction in the amount of energy product used per unit of output. In the residential sector, an energy efficiency increase for space heating or water heating is defined as the reduction in energy consumed in these activities on a per capita basis. This efficiency is achieved by such means as increased insulation and better heat transfer. However, these energy efficiencies have not been quantified by type for purposes of ORBES.[11]

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[10] See U.S. Congress, Office of Technology Assessment, Energy from Biological Processes (OTA-E-124, July 1980), and Materials and Energy from Municipal Waste (OTA-M-93, July 1979).

Cogeneration. The second major factor that accounts for the low energy growth rate in the conservation case is the assumption that cogeneration will be employed on a wide scale in the ORBES region. Cogeneration means the combined production of power, either mechanical or electrical, and of useful thermal energy such as process steam. Expressed differently, the heat rejected from one process becomes the energy input into a subsequent process. On a national basis, waste heat from electrical generation and process steam production amounted to the energy equivalent of over 7 million barrels of oil per day in 1975. Because of its fuel savings potential and other benefits, interest in cogeneration as an energy conservation measure has been renewed in both industry and utilities.[12]

Using currently available technology, cogeneration systems incorporate either a "bottoming cycle" or a "topping cycle" configuration. These terms refer to the point in the cogeneration system at which the electrical or mechanical energy is produced. In bottoming cycle configurations, fuel is burned initially to produce process heat, with the rejected heat used to generate either electrical or mechanical power. However, industrial process heat requirements (400 degrees Fahrenheit or lower) usually are too low for the rejected heat to be used effectively in power generation. Although technology may overcome this problem, at present no complete, reliable, and problem-free system exists. Therefore, apart from occasional installations, the bottoming cycle is not expected to have a major impact on industrial fossil fuel demand within the next 8 to 10 years.

In a topping cycle configuration, fuel is burned to produce high-temperature heat, which is expanded through a turbine to generate electrical or mechanical power. After passing through the turbine, the rejected heat is then used in industrial applications as process heat. Because of the energy required to generate the electrical or mechanical power, more fuel is consumed in a cogeneration system than in the production of process heat alone. However, the total fuel required to produce both power and process heat in one system is less than the fuel required to produce power and heat in separate systems. For example, the overall efficiency of a steam turbine topping cycle cogeneration system is about 79 percent, compared with the combined efficiency of 58 percent for two separate systems.

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[11] Page, Gilmore, and Hewings, An Energy and Fuel Demand Model.

[12] The information on cogeneration is taken from two sources: Robert Stobaugh and Daniel Yergin, eds., Energy Future (New York: Random House, 1979), and U.S. Comptroller General, Industrial Cogeneration--What It Is, How It Works, Its Potential (EMD-80-7, April 29, 1980).

Topping cycle systems are of two types. In the first, fuel is burned in either a gas turbine or a diesel engine that produces electric or mechanical power directly. The exhaust is used to provide process heat or, with the addition of a heat recovery boiler, process steam. In the second type, fuel is burned initially to produce high-pressure steam, which is then passed through a steam turbine to produce power. The exhaust is used to provide process steam.

Cogeneration systems and components must be selected for compatibility with the industrial processes that they complement. Thus, selection on a site-by-site basis is necessary. The most important distinguishing features of these systems are the fuels that can be used, the capital investment required, the efficiency in converting fuel to electricity, the electricity produced per unit of steam generated, and the resulting effects on the environment. Each choice carries its own advantages and disadvantages. For example, no pollution control equipment is needed to control particulates and sulfur oxides from gas turbines, but expensive devices are required to control the high sulfur dioxide and particulate emissions from steam turbines fueled by certain types of coal. However, the steam turbine is the only commercially available cogeneration system that can use coal for fuel. The use of coal instead of liquid or gaseous fuels in a steam cogeneration system increases capital costs and could make the system uneconomical. As a result, coal-fired steam turbines are usually not considered except for large applications where economies of scale are possible. On the other hand, the development of alternative liquid fuels and of gasifiers capable of using coal, biomass, or other alternative fuels could greatly increase the prospects for cogeneration.

The major difference between industrial and utility cogeneration is which output drives the system. Cogeneration systems can be designed for process steam requirements, with electricity as a secondary consideration, or their design can be reversed, with electric power as the primary requirement.

In the following chapter, impacts in the ORBES region are compared among the natural gas substitution scenario, the nuclear fuel substitution scenario, the alternative fuel substitution scenario, and the conservation emphasis scenario. As in the presentation of the comparative impacts of the coal-dominated scenarios (see chapter 6), the major sections deal with emissions, concentrations, and air-quality-related impacts (section 14.1); economic impacts related to air quality impacts (section 14.2); and other impacts related to expanded electrical generating capacity (section 14.3). In addition, in section 14.4, there is an overview of the impacts projected under each of the fuel substitution and conservation scenarios.

14. Impacts of the Fuel Substitution and Conservation Scenarios

A comparison of the three fuel substitution scenarios and the conservation emphasis scenario demonstrates that, under all these scenarios, the emission-related impacts that are projected to occur under base case, coal-dominated conditions would be reduced. Other across-the-board comparisons, however, are more difficult to make since not all impact areas were examined under each of these scenarios. As a result, all of the fuel substitution and conservation scenarios are discussed together rather than separately. In section 14.4, however, there is a brief synopsis of the general trends under each scenario.

See chapter 13 for descriptions of the conservation emphasis scenario, the natural gas substitution scenario, the nuclear fuel substitution scenario, and the alternative fuel substitution scenario.

14.1 Emissions, Concentrations, and Air-Quality-Related Impacts

SULFUR DIOXIDE EMISSIONS. Utility sulfur dioxide emissions would be only slightly lower in 2000 under the fuel substitution and conservation scenarios than they would be under the base case even though substantially fewer coal-fired units would be needed under these scenarios than under the base case (see table 14-1).[1] The conservation emphasis case would reduce utility sulfur dioxide emissions the most (resulting in emissions 11 percent lower than under the base case), and the nuclear substitution case would reduce utility sulfur

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[1] For a discussion of air pollutant emissions and the resulting concentrations under the natural gas substitution case, see James J. Stukel and Brand L. Niemann, *Documentation in Support of Key ORBES Air Quality Findings*; Teknekron Research, Inc., *Air Quality and Meteorology in the Ohio River Basin: Baseline and Future Impacts*; and Teknekron Research, Inc., *Selected Impacts of Electric Utility Operations in the Ohio River Basin (1976-2000): An Application of the Utility Simulation Model* (volumes I, II, and III, respectively, of James J. Stukel, ed., *Ohio River Basin Energy Study: Air Quality and Related Impacts* (ORBES Phase II)). Emissions under the nuclear fuel substitution scenario and the conservation emphasis scenario are presented in Teknekron Research, Inc., *The Calculation of Several Measures for ORBES Scenarios 2a, 2c, and 6* (RM-032-EPA-80, June 1980).

Table 14-1
Sulfur Dioxide, Particulate, and Nitrogen Oxide Emissions, ORBES Region, Fuel Substitution and Conservation Emphasis Scenarios, Year 2000

	Sulfur Dioxide Emissions	Particulate Emissions	Nitrogen Oxide Emissions
		(millions of tons)	
1976	8.94	1.38	1.49
Base Case	4.35	0.19	2.00
Natural Gas Substitution	3.93	0.16	1.51
Nuclear Fuel Substitution	4.21	0.18	1.84
Conservation Emphasis	3.87	0.16	1.47

Note: Emission levels were not calculated for the alternative fuel substitution case.

dioxide emissions the least (resulting in emissions only 3 percent lower than under the base case).

The expanded use of generating units governed by state implementation plans (SIPs) explains why the fuel substitution and conservation scenarios would result in utility sulfur dioxide emissions quite similar to those of the base case. Under both the conservation emphasis case and the natural gas substitution case, fewer new generating units (75 and 61 fewer units, respectively) would be built than under the base case; under the nuclear substitution case, half of the new units added after 1985 would be nuclear fueled rather than coal fired. As a result, SIP-regulated generating units would be used more than they would under the base case, where some of the electrical generation would shift to new, cleaner units governed by revised new source performance standards (RNSPS). However, the specific emission levels of SIP units were calculated only for the natural gas substitution case. Under this case, SIP units would account for about 35 percent of the electrical generation in the year 2000, whereas they would account for 24 percent under the base case. Thus, while sulfur dioxide emissions from SIP-regulated units would account for 67 percent (or 2.93 million tons) of the sulfur dioxide emitted in the year 2000 under the base case, under the natural gas case such emissions not only would be higher (3.05 million tons) but also would account for more of the total emissions (78 percent of the 3.93 million tons emitted in 2000).

PARTICULATE EMISSIONS. Utility particulate emissions would be lower under all of the fuel substitution and conservation scenarios than they would be under the base case. However, again because of the expanded use of SIP units to generate electricity, these emissions would be only slightly lower than under the base case (see table 14-1).

NITROGEN OXIDE EMISSIONS. Unlike the coal-dominated scenarios, however, the fuel substitution and conservation scenarios would not raise utility nitrogen oxide emissions at all or as much (see table 14-1). Such emissions rise in proportion to increased generating capacity, and less capacity is installed under all of the substitution and conservation scenarios than under the base case. In fact, under the conservation emphasis case, utility nitrogen oxide emissions would be lower in the year 2000 than in 1976, and under the natural gas substitution case, the 1976 emission levels would be increased by only 1 percent. In contrast, the strict environmental control case would result in the lowest utility nitrogen oxide emissions in 2000 of all of the coal-dominated cases, and it still would increase utility nitrogen oxide emissions about 34 percent over the 1976 levels. Of the fuel substitution and conservation scenarios, only the nuclear substitution case would raise utility nitrogen oxide emissions significantly (about 23 percent) from the 1976 levels. Even this increase, however, would result in lower emission levels than any of those projected for the coal-dominated scenarios.

SULFUR DIOXIDE AND SULFATE CONCENTRATIONS. Although annual and episodic concentrations, related crop losses, and emission-related mortality were not examined consistently under the fuel substitution and conservation scenarios, a few general observations can be made using the patterns that emerged from the coal-dominated scenario analyses. For example, since the reduction of utility sulfur dioxide emissions consistently would result in reductions in annual and episodic sulfur dioxide and sulfate concentrations, and since all of the fuel substitution and conservation scenarios would reduce these emissions more than the base case would, such sulfur dioxide and sulfate concentrations should be lower in 2000 under any of the fuel substitution and conservation scenarios than under the base case. This observation is confirmed by calculations performed for the natural gas substitution case. Under this scenario, episodic sulfur dioxide and sulfate concentrations would be 25 and 15.6 percent lower, respectively, in the year 2000 than they would be under the base case in that year. Annual average concentrations also would be lower under the natural gas case, although not as dramatically. Figures 14-1 and 14-2 compare the annual average sulfur dioxide and sulfate concentrations under the base case and the natural gas case. As can be seen, the area affected by concentrations of a given magnitude would be slightly smaller under the latter case than under the former. In general, annual

Figure 14-1
Annual Average Sulfur Dioxide Concentrations, Electric Utility Contribution

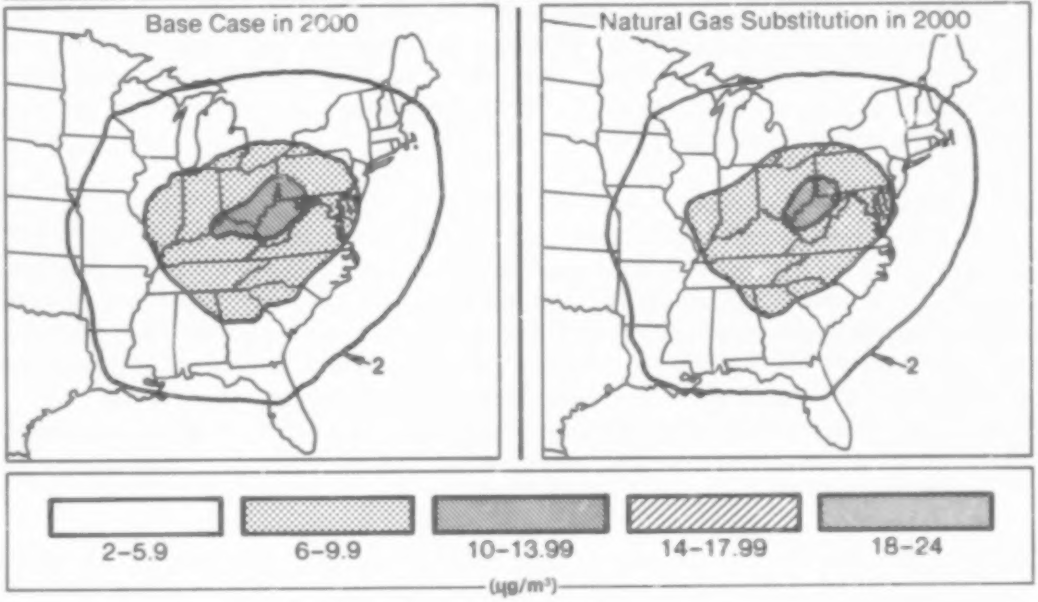
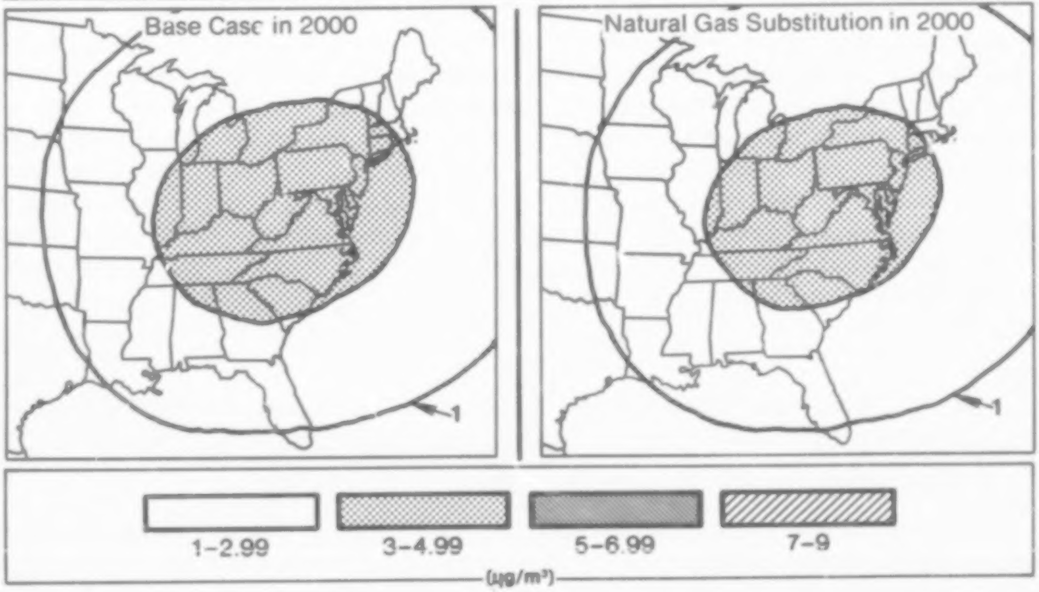

Base Case in 2000
Natural Gas Substitution in 2000
2
2
2–5.9
6–9.9
10–13.99
14–17.99
18–24
(μg/m³)

Figure 14-2
Annual Average Sulfate Concentrations, Electric Utility Contribution


Base Case in 2000
Natural Gas Substitution in 2000
1
1
1–2.99
3–4.99
5–6.99
7–9
(μg/m³)

average concentrations would be about 7 percent lower under the natural gas case in the year 2000 than under the base case in that year.

PHYSICAL CROP LOSSES. Crop losses in the year 2000 due to utility-related sulfur dioxide concentrations in the presence of moderate ozone levels (0.06 to 0.1 parts per million) also should be lower under any of the fuel substitution and conservation cases than they would be under the base case.[2] However, even under the base case such crop losses would represent less than 1 percent of the total regional yield.

It is the crop losses due to oxidants formed from nitrogen oxide emissions that these substitution and conservation scenarios should reduce the most. As may be recalled, by the year 2000 utility nitrogen oxide emissions may dictate the level of ozone-related crop losses because the nitrogen oxide emissions from transportation sources are projected to decrease substantially between 1985 and 2000. Since the fuel substitution and conservation scenarios would result in utility nitrogen oxide emissions significantly or substantially lower than those under the coal-dominated scenarios, related crop losses also should be significantly to substantially lower under the former scenarios than under the latter ones.

MORTALITY. The mortality related to air quality should decrease under all of the fuel substitution and conservation scenarios from that projected under the coal-dominated scenarios since emission levels would decrease more under the former group of scenarios than under the latter.[3] As discussed in section 4.6, substantial controversy exists about the quantification of deaths related to air quality. Nevertheless, an analysis of the projected deaths related to sulfates and particulates under the natural gas substitution case bears out this observation. Under this case, the cumulative deaths related to sulfate air pollution by regional electrical generating facilities between 1975 and 2000 are estimated to be 21 percent lower than they would be under the base case. Annual sulfate-related deaths would be 34 percent lower in 1985 under the base case; in 2000, such deaths would be 36 percent lower under the natural gas case. Particulate health impacts also would be lower under the natural gas substitution case. Cumulative particulate-related deaths between 1976 and 2000 would be 11 percent lower under the natural gas substitution case than under the base case.

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[2] For a discussion of vegetation impacts and losses, see Orie Loucks et al., Crop and Forest Losses Due to Current and Projected Emissions from Coal-Fired Power Plants in the Ohio River Basin (ORBES Phase II).

[3] See Maurice A. Shapiro and A.A. Sooky, Ohio River Basin Energy Study: Health Aspects (ORBES Phase II).

14.2 Economic Impacts Related to Air Quality Impacts

UTILITY COSTS. In terms of the monetary costs to the utilities for these lower emissions, two of the fuel substitution scenarios (natural gas and nuclear) and the conservation emphasis scenario should result in lower cumulative pollution control costs and lower cumulative capital costs to install new coal-fired capacity than would the base case (see figure 14-3).[4] These reductions would be the direct result of decreased coal-fired electrical generating capacity under all of these scenarios. However, when the costs of installing nuclear-fueled capacity under the nuclear substitution case are added, the result is total costs about 10 percent higher than the total costs under the base case. The nuclear substitution case would result in these higher costs because the cost of building a nuclear plant is approximately 20 percent greater than the cost of building a comparable coal-fired plant.

CONSUMER COSTS. Consumer costs were calculated only for the natural gas substitution case. Thus, the exact economic benefits for the consumer of reduced pollution control costs and of reduced capital costs are unknown for the other fuel substitution scenarios and for the conservation emphasis scenario. Under the natural gas substitution case, total revenues collected from consumers between 1976 and 2000 would be lower (by about 26 percent) than the total revenues collected under the base case between the same years. Yet the actual price of electricity in 2000 under the natural gas case would be only 0.2 percent lower in 2000 than it would be under the base case. The reason for this similarity in the year 2000 is that similar electricity demand growth rates were assumed for these two scenarios between 1985 and 2000. Between these years, an average annual rate of 1.6 percent is assumed for the natural gas case; an average annual rate of 2.1 percent, for the base case.

14.3 Other Impacts Related to Expanded Capacity

LAND. Under all of the fuel substitution cases and the conservation emphasis case, fewer generating facilities would be required than under the base case. As a result, land conversion would range from slightly to substantially lower under these substitution and conservation scenarios than under the base case

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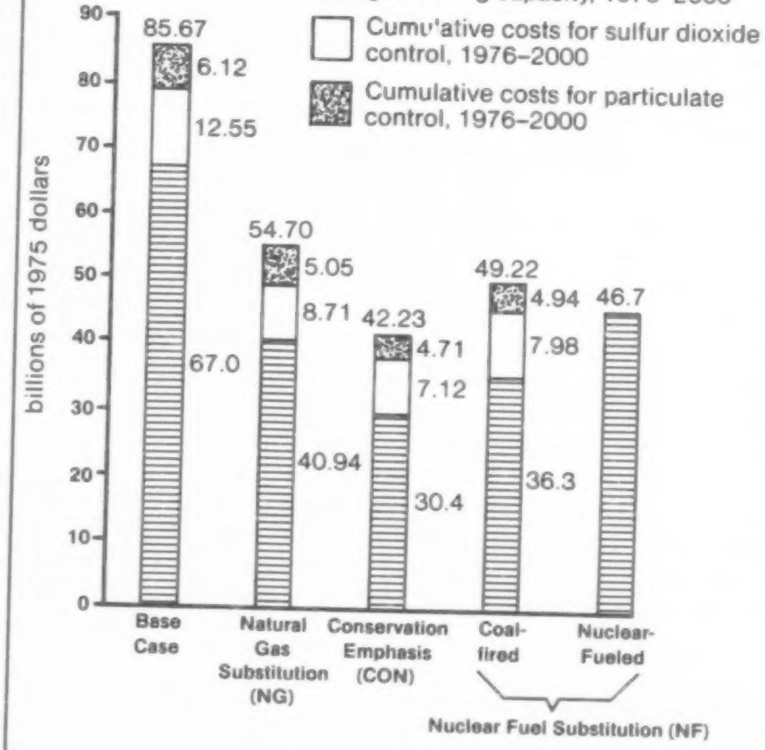
[4] For calculations of both utility costs and consumer costs under the natural gas substitution scenario, see Teknekron Research, Inc., Selected Impacts of Electric Utility Operations in the Ohio River Basin. For calculations of utility costs under the nuclear fuel substitution scenario and the conservation emphasis scenario, see Teknekron Research, Inc., The Calculation of Several Measures for ORBES Scenarios 2a, 2c, and 6. The costs of the alternative fuel substitution scenario were not calculated.

Figure 14-3
Cumulative Capital Costs, Base Case, Fuel Substitution Scenarios, and Conservation Emphasis Scenario, 1976–2000

Note: The same nuclear capacity was assumed under all scenarios but the nuclear fuel substitution case. For all scenarios but the nuclear case, cumulative capital costs for nuclear-fueled capacity were $8.3 billion.



Cumulative sulfur dioxide and particulate control costs

Scenario	Costs billion $	% total costs
BC	18.67	21.8
NG	13.76	25.1
CON	11.83	28.0
NF	12.92	26.2

(see table 14-2).[5] However, under all of these scenarios, land conversion would represent less than 1 percent of regional acreage, although in some state portions more land would be converted under some scenarios than others. Of the fuel substitution and conservation scenarios, the nuclear substitution scenario has the highest installed capacity and thus would require the most land conversion.

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[5] For a full discussion of land impacts, see J.C. Randolph and W.W. Jones, Ohio River Basin Energy Study: Land Use and Terrestrial Ecology (ORBES Phase II).

In terms of the land types that would be converted for new generating units, less agricultural, forest, public, and other land would be converted under all of the fuel substitution and conservation scenarios--except the nuclear substitution scenario--than under the base case (see table 14-2). Under the natural gas substitution case, the conversion of these land types would range from 34 to 43 percent lower than under the base case; under the alternative fuel substitution case, from 12 to 19 percent lower; and under the conservation emphasis case, from 40 to 52 percent lower. The nuclear fuel substitution case, however, would result in a slightly higher conversion of agricultural lands than would the base case. This higher conversion would occur because no nuclear-fueled scenario additions are built in the ORBES state portions of Kentucky and West Virginia. Rather, more units are sited in Illinois, where there is more agricultural land than forest, public, or other types of land. Finally, because of the siting assumptions of each scenario, the fuel substitution or conservation scenario that would convert the most or the least of any land type within a state will vary.

The amount of land that would be converted for all energy uses (new electrical generating facilities, new transmission line rights-of-way, and new surface mining for utility coal) was examined only under the alternative fuel substitution case. Under that case, 10 percent less land would be converted for all energy-related uses than would be converted under the base case. However, the amount of land required for the alternative sources was not analyzed. Indeed, the total land requirements for the alternative fuel substitution case might not be very different from those of the scenarios requiring conventional fuels. The regional acreage that would be affected by surface mining for coal to supply electrical generating facilities under the alternative case would be 8 percent less than under the base case, ranging from 4 percent less in the ORBES state portion of Indiana to 12 percent less in the Illinois portion. Surface mining for all purposes would affect 4 percent less acreage under the alternative fuel substitution case than under the base case.

The nuclear substitution case would result in the highest assessment of regional terrestrial ecosystem units of all the fuel substitution and conservation scenarios (see table 14-3). Moreover, the ecosystem units assessed under nuclear substitution would be highly concentrated in the ORBES state portion of Illinois. Because of the siting assumptions of each scenario as well as the county-level assumptions of the terrestrial ecosystem analysis, the scenario that would result in the highest or lowest unit assessment within a state will vary.

EMPLOYMENT. Since the construction and operation of coal-fired power plants would not increase rapidly under any of the fuel substitution and conservation

Table 14-2
Land Converted for Electrical Generating Facilities, ORBES Region, Base Case, Fuel Substitution Scenarios, and Conservation Emphasis Scenario, 1976–2000

State Portion	Base Case	Natural Gas Substitution	Nuclear Fuel Substitution	Alternative Fuel Substitution	Conservation Emphasis
			(acres)		
Illinois					
Agricultural	23,046	16,993	43,358	21,689	15,194
Forest	3,179	2,144	5,124	2,463	1,905
Public	356	301	657	334	290
Other	1,947	1,395	4,031	1,846	1,263
	28,528	20,833	53,170	26,332	18,652
Indiana					
Agricultural	25,674	19,771	27,237	23,716	17,616
Forest	9,799	6,430	8,997	7,954	5,621
Public	1,009	800	811	877	690
Other	3,058	1,490	2,235	2,572	1,248
	39,540	28,491	39,280	35,119	25,175
Kentucky					
Agricultural	20,425	11,161	12,679	17,994	11,043
Forest	12,508	7,988	8,872	10,706	8,135
Public	313	155	169	224	166
Other	3,187	1,322	1,463	1,982	1,614
	36,433	20,626	23,183	30,906	20,958
Ohio					
Agricultural	13,122	7,195	10,546	10,504	7,322
Forest	14,175	7,133	8,561	10,852	6.266
Public	1,700	738	791	1,280	464
Other	2,575	1,824	2,364	2,255	2,002
	31,572	16,890	22,262	24,891	16,054

scenarios, neither would related employment under these scenarios.[6] Compared to the base case, for example, the number of construction and operation

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[6] For employment projections, see Steven I. Gordon and Anna S. Graham, Regional Socioeconomic Impacts of Alternative Energy Scenarios for the Ohio River Basin Energy Study Region (ORBES Phase II).

Table 14-2 (continued)
Land Converted for Electrical Generating Facilities, ORBES Region, Base Case, Fuel Substitution Scenarios, and Conservation Emphasis Scenario, 1976–2000

State Portion	Base Case	Natural Gas Substitution	Nuclear Fuel Substitution	Alternative Fuel Substitution	Conservation Emphasis
Pennsylvania					
Agricultural	8,315	5,554	4,935	6,990	4,790
Forest	14,347	8,248	10,988	12,605	7,077
Public	1,120	449	383	825	361
Other	4,208	2,639	2,793	3,065	2,450
	27,990	16,890	19,099	23,485	14,678
West Virginia					
Agricultural	4,598	2,907	5,569	3,805	1,891
Forest	13,148	10,253	9,659	12,821	6,429
Public	352	319	678	367	176
Other	1,708	802	1,348	1,146	261
	19,806	14,281	17,255	18,139	8,757
ORBES Region Total					
Agricultural	95,920	63,581	111,815	84,698	57,856
Forest	67,311	42,196	58,562	57,401	35,433
Public	4,827	2,762	3,633	3,907	2,147
Other	15,809	9,472	15,238	12,866	8,838
	183,869	118,011	174,249	158,872	104,274

workers needed would be much lower under the natural gas case (38 percent lower), the alternative fuel case (19 percent lower), and the conservation emphasis case (50 percent lower). (See figure 14-4.) However, employment related to the increased use of natural gas or alternative fuels was not calculated, and, in fact, could compensate for the lower demand for workers on coal-fired power plants.

Of the fuel substitution and conservation scenarios examined, all would result in the need for fewer skilled laborers--boilermakers, pipefitters, and electricians--than would the base case. The natural gas substitution case would require 31 percent fewer skilled workers for power plant construction and operation in 1990 (the peak construction year), and the conservation emphasis case would require 40 percent fewer skilled workers for such

Table 14-3
Terrestrial Ecosystem Assessment Units, Base Case, Fuel Substitution Cases, and Conservation Emphasis Case, 1976–2000

State Portion	Base Case	Natural Gas Substitution	Nuclear Fuel Substitution	Alternative Fuel Substitution[1]	Conservation Emphasis
Illinois	356	309	679	334	258
Indiana	451	331	425	386	301
Kentucky	266	148	167	213	129
Ohio	305	170	212	247	161
Pennsylvania	270	134	216	196	118
West Virginia[2]	156	87	87	122	71
ORBES Region Total	1804	1179	1786	1498	1038

[1] Impacts of alternative fuel technology sitings are not included in the analysis.

[2] No substate endangered vertebrate species data were available for West Virginia.

construction and operation in 1990. However, the labor requirements associated with expanded natural gas use and conservation were not calculated.

The alternative fuel substitution case also would require fewer skilled workers in 1990 (about 33 percent fewer) than would the coal-dominated base case in that year. However, the surplus of skilled workers could be offset by a demand for labor to implement a substitution of alternative fuels. This demand might be two to three times as great as the demand for power plant construction and operation under the base case.[7] Thus, some retraining might be required so that unemployed power plant construction workers could be used to install alternative energy systems. However, no skill breakdowns were calculated for the workers associated with the alternative fuel systems.

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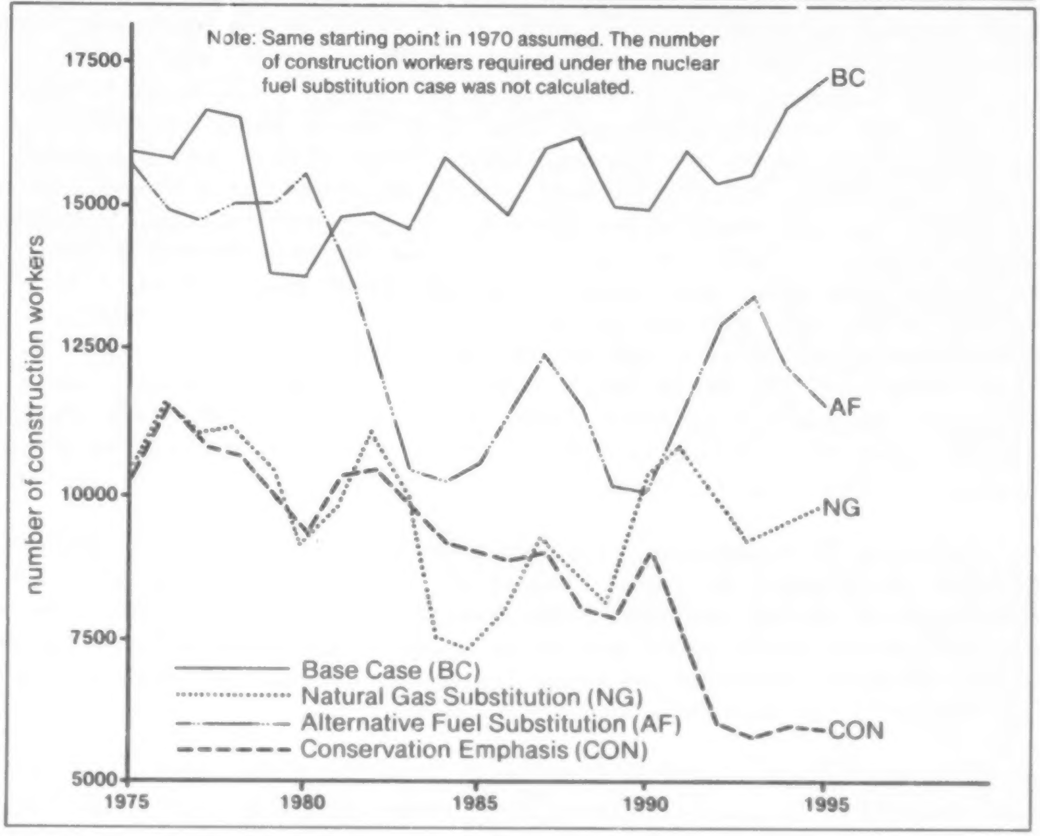
[7] For such estimates of alternative fuel labor requirements, see testimony before the Subcommittee on Energy, Joint Economic Committee, U.S. Congress (2d session, March 1978, pp. 28, 51, 95, and 136). Similar estimates have been given in other studies. For references, see Gordon and Graham, Regional Socioeconomic Impacts of Alternative Energy Scenarios.

Figure 14-4
Construction Workers, Base Case, Fuel Substitution Scenarios, and Conservation Emphasis Scenario, 1975–95



Because fewer coal-fired generating units are sited and because growth is lower in most sectors, less coal should be needed under all of the fuel substitution and conservation scenarios than would be needed under the base case. However, coal production under these substitution and conservation scenarios still would be higher than in 1974. For example, of the scenarios examined, coal production for all purposes would be 14 percent lower in 2000 under the alternative fuel substitution case and 35 percent lower in 2000 under the natural gas substitution case than the production for all purposes under the base case in 2000. Nevertheless, coal production for all purposes would be 59 percent higher in 2000 under the alternative fuel case and 21 percent higher in 2000 under the natural gas case than the production for all purposes in 1974. In comparison, coal production for all purposes would be 85 percent higher in 2000 under the base case than in 1974.[8]

Because coal production for all purposes should rise under all of the fuel substitution and conservation scenarios, coal-mining employment also would increase, although not as much as it would under the base case. Between 1970 and 2000, coal-mining employment would increase between 24 and 154 percent under the alternative fuel case, depending on the county; under the base case, the increase would range from 35 to 222 percent. Under the natural gas substitution case, the increase would range from 9 to 55 percent. In general, therefore, since employment simply would rise at a slower rate under the natural gas and conservation scenarios, no negative coal-mining employment impacts should be felt. In fact, 131 of the 152 coal-producing counties in the ORBES region would experience mining employment growth rates of 50 percent or more under the alternative case. In comparison, 121 counties would experience such rates under the natural gas case; 134 counties, under the base case. However, if county-level population increases should exceed the employment increases, negative county-level impacts that might have been avoided under the coal-dominated scenarios might be experienced under the substitution and conservation scenarios.

Certainly it appears that the coal demand associated with a substitution of other fuels would not be as beneficial to some coal-mining areas as would implementation of the coal-dominated scenarios. However, it should be noted that positive benefits could accrue to urban areas, where alternative energy systems would be developed and where a sufficient supply of labor exists and a good supply of the services required is present.

WATER. Regional water quality impacts would be about the same under both the fuel substitution and conservation scenarios and the coal-dominated scenarios.[9] In fact, no changes would be registered in base case protection levels and base case aquatic habitat impacts for any river under any of the fuel substitution and conservation scenarios (see table 14-4). This across-the-board similarity, as discussed in chapter 6, results primarily because of high background concentrations alone or in conjunction with municipal and industrial consumption. In comparison to these causes, power plant

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[8] For coal production estimates, see Donald A. Blome, Coal Mine Siting for the Ohio River Basin Energy Study (ORBES Phase II).

[9] For discussion, see Clara Leuthart and Hugh T. Spencer, Fish Resources and Aquatic Habitat Impact Assessment Methodology for the Ohio River Basin Energy Study Region (ORBES Phase II).

Table 14-4
Aquatic Habitat Impacts, Fuel Substitution and Conservation Emphasis Scenarios, 7-Day–10-Year Low Flow, Compared with Base Case Impacts, 7-Day–10-Year Low Flow

River	Natural Gas Substitution		Nuclear Fuel Substitution		Alternative Fuel Substitution		Conservation Emphasis	
	Water Quality Impact Index (Range: 0–100) if changed	Number of Units Added or Removed from Base Case	Water Quality Impact Index (Range: 0–100) if changed	Number of Units Added or Removed from Base Case†	Water Quality Impact Index (Range: 0–100) if changed	Number of Units Added or Removed from Base Case	Water Quality Impact Index (Range: 0–100) if changed	Number of Units Added or Removed from Base Case
Allegheny	29	− 6	31	− 6C + 1N	31	− 2	21	− 7
Beaver	30	− 3	30	− 3C	31	− 2	30	− 3
Big Muddy								
Big Sandy								
Cumberland								
Great Miami								
Green								
Illinois	25	− 7	34	− 8C +13N	25	− 3	25	− 8
Kanawha								
Kaskaskia								
Kentucky	*		*		*		*	
Licking								
Little Miami								
Mississippi			23	+ 5N		− 1		− 1
Monongahela			42	+ 2N		− 1		− 1
Muskingum	39	− 2	39	− 2C			39	− 2
Ohio Main Stem	40	−47		− 7C + 3N		−23	40	−54
Rock	*	− 2	*	− 2C + 2N	*		*	− 2
Salt	*		*		*		*	
Scioto		− 2		− 2C		− 2		− 2
Susquehanna	*	− 1	*	− 1C	*			− 1
Wabash				−2C +2N			20	− 3
White								
Whitewater	*						*	

Note: Protection levels, overall aquatic habitat impacts (light, moderate, heavy, or drastic), and the cause of those impacts would remain the same as under the base case on all rivers under the fuel substitution and conservation scenarios.

*Background information not available; analysis not completed

†C = coal-fired unit; N = nuclear-fueled unit

consumption would have only an incremental impact on most of the streams under all scenarios.

Thus, for example, both the base case and all four of the fuel substitution and conservation scenarios are projected to result in the same (heavy) aquatic habitat impacts on the Ohio River main stem in the year 2000 under 7-day-10-year low flow conditions. This projection holds even though widely different capacities are sited on the Ohio River main stem under these scenarios (see table 14-4). Moreover, under all these scenarios, the major cause of these heavy impacts is projected to be the high background levels either alone or in conjunction with municipal and industrial consumption.

As also emphasized in chapter 6, it appears that, under the natural phenomenon of 7-day-10-year low flow, such impacts probably could not be avoided unless background concentrations are reduced. However, it also appears unlikely that these concentrations will be reduced during the time frame of this study since nonpoint and geochemical sources are primarily responsible for the high concentrations and are unlikely to be controlled by the year 2000.

HEALTH. A regional substitution of other fuels for coal or a regional emphasis on conservation would reduce the annual deaths and injuries attributable to coal mining, coal processing, and coal transportation (see table 14-5).[10] Moreover, under the nuclear substitution case, there would be an increase in the illnesses and deaths of uranium miners, workers exposed to radiation, and the general public. National-level health impacts for the nuclear fuel cycle were projected for the year 2000 in terms of impacts per 1000 megawatts per year of electrical generation.[11] According to the rates derived, the general population could experience 0.11 to 0.31 cancers per 1000 megawatts per year of nuclear-fueled generation, based on the assumption that plutonium is recycled. Occupational workers would experience the following rates per 1000 megawatts generated: 1.4 to 1.7 cancers (on the assumption that whole-body exposures are reduced by one-half); 1 trauma incidence (based on the assumption that injury morbidity is reduced by one-half and that silicosis is eliminated); and 0.5 chronic lung diseases.

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[10] See Shapiro and Sooky, Ohio River Basin Energy Study: Health Aspects.

[11] Projections of national-level health impacts of nuclear-fueled generation are given in Edward P. Radford, Impacts on Human Health from the Coal and Nuclear Fuel Cycles and Other Technologies Associated with Electric Power Generation (ORBES Phase II). These projections are derived from the May 1979 draft report of the Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR Committee), U.S. National Academy of Sciences.

Table 14-5
Health Impacts Related to Coal Mining, Processing, and Transportation, Base Case, Fuel Substitution Scenarios, and Conservation Emphasis Scenario, Year 2000

	Base Case	Natural Gas Substitution	Nuclear Fuel Substitution	Alternative Fuel Substitution	Conservation Emphasis
Coal Mining					
Accidental deaths	75	54	53	65	50
Disabling injuries	5359	3860	3814	4638	3513
Nondisabling injuries	4435	3194	3156	3838	2907
Coal Processing					
Accident deaths	9	6	6	7	6
Disabling injuries	472	340	336	408	309
Nondisabling injuries	1019	734	725	882	668
Coal Transportation					
Vehicle miles traveled					
Deaths	12	9	—	10	—
Injuries	26	19	—	23	—
Weight transported					
Deaths	50	36	—	44	—
Injuries	123	88	—	107	—

Under present conditions, it is not possible to quantify the health consequences of an accidental release of radioactivity. The primary factor that would govern exposure of the surrounding population to radiation is whether the primary containment vessel is breached.

14.4 Overview

NATURAL GAS SUBSTITUTION. Under the natural gas substitution case, utility sulfur dioxide, particulate, and nitrogen oxide emissions and annual and episodic concentrations of sulfur dioxide and sulfates would be slightly lower than under the base case. The price of electricity under the two cases, however, would be only slightly different in 1985 and nearly identical in 2000. Water quality and aquatic habitat impacts also would be similar under both cases. On the other hand, the amount of land converted for electrical generating facilities, the number of terrestrial ecosystem units assessed, and the employment related to power plant construction and operation would be about one-third lower under the natural gas case than under the base case.

NUCLEAR FUEL SUBSTITUTION. Under the nuclear fuel substitution case, utility sulfur dioxide, particulate, and nitrogen oxide emissions, land conversion for electrical generating facilities, and the number of terrestrial ecosystem units assessed would be slightly lower in 2000 than they would be under the base case. Water quality and aquatic habitat impacts would be about the same under both cases, while the health problems related to coal mining and coal processing probably would be lower under the nuclear case than under the base case. The possible health problems associated with nuclear-fueled generation would increase under the nuclear substitution case.

ALTERNATIVE FUEL SUBSTITUTION. Under the alternative fuel substitution case, regional land use conversion for electrical generating facilities and the number of terrestrial ecosystem units assessed should be lower. Water quality and employment impacts, however, would be about the same under both cases. The health impacts associated with coal mining and coal processing would be lower under the alternative fuel substitution case.

CONSERVATION EMPHASIS. Under the conservation emphasis case, regional utility sulfur dioxide, particulate, and nitrogen oxide emissions would be lower than the levels projected under the base case, as would pollution control costs and capital costs. The conservation case also would entail the lowest land use conversion for generating units and the lowest terrestrial ecosystem unit assessment of all the cases analyzed. Finally, water quality impacts would be about the same under both the conservation case and the base case, while the conservation case would call for only about half of the labor required under the base case for power plant construction and operation.

15. Institutional Considerations: Nuclear Energy, Alternative Fuels, and Conservation

In this chapter, the focus is on the institutional barriers and opportunities that would be associated with the implementation of the nuclear substitution, alternative fuel substitution, and conservation emphasis scenarios.[1] The impacts of these scenarios in the Ohio River Basin Energy Study (ORBES) region are discussed in chapter 14.

As emphasized in previous chapters, neither conservation nor any of the fuel substitutions for coal is considered likely to contribute substantially to regional or national energy supplies, at least by the end of this century. However, the conservation case is the most plausible option among the three; conservation already is making inroads in the region and the nation. The conservation emphasis case would require improvements in end-use efficiencies and changes in lifestyle, but no radically new technologies. On the other hand, especially in the coal-dominated ORBES region, a major increase in the proportion of electricity generated by nuclear fuels is not expected to occur. This is due in large measure to political constraints. In addition, a major shift to alternative fuels would require more extensive technological and institutional changes than are considered possible in the next 20 years.

15.1 Nuclear Energy

Even before the nuclear accident at the Three Mile Island plant near Harrisburg, Pennsylvania, in March 1979, it was considered extremely unlikely that a large number of additional nuclear-fueled generating units would come on-line in the region, permitting nuclear fuel to penetrate the present coal emphasis to any major extent.[2] However, many nuclear energy supporters around the nation still contend that nuclear-fueled units should be constructed even in areas where coal is plentiful. Nevertheless, at present three of the six ORBES states seem to be placing institutional barriers on any greater reliance on this form of electrical generation. In Kentucky and West Virginia, both state and local governments oppose nuclear energy strongly; no nuclear-fueled plants are located or planned in either state. The basis for the opposition appears to be both fear of nuclear power and the concern that it would make coal less attractive as a fuel. In addition, since it occurred in 1979, the Three Mile Island accident has appeared to intensify opposition by Pennsylvania residents to the construction of additional nuclear-fueled plants.[3]

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[1] Existing institutional mechanisms would be adequate to handle a major increase in the use of natural gas. Therefore, implementation of the natural gas substitution scenario is not considered in this chapter.

[2] Three Mile Island is close to but not within the ORBES region.

The opposition to nuclear power, which among the ORBES states is particularly apparent in Kentucky, Pennsylvania, and West Virginia, arises from a number of factors, including the doctrine of federal preemption, increased concern over the health effects of low- and high-level radiation, and growing dissatisfaction with the benefits of nuclear energy.

PREEMPTION. The central question in relation to the preemption doctrine and the use of nuclear fuels is whether a state may legally pass legislation to control the placement of nuclear facilities or the transportation or storage of nuclear materials within its borders.

In 1972, the U.S. Supreme Court held (Northern States Power Co. v. Minnesota, 282 U.S. 834) that the Atomic Energy Act gave the U.S. Atomic Energy Commission (now the Nuclear Regulatory Commission) the exclusive authority to regulate radioactive waste releases so as to preclude any regulatory authority by the state of Minnesota. At present, however, many legal scholars would argue that, because of an apparent shift in the Court's views and the development of a complex body of law on intergovernmental nuclear issues and on other environmental and energy issues since 1972, the Court would not summarily affirm that decision.

A few states in the nation have attempted to prohibit the further development of nuclear energy within their boundaries by placing nuclear moratorium initiatives on the ballot, but the constitutionality of such initiatives is uncertain. States also have attempted to circumvent the federal preemptive doctrine by turning to forms of indirect regulation through such traditional state powers as zoning, site certificate requirements, and economic regulation of all sales from electrical generators (including nuclear-fueled units). Perhaps the most important point to emphasize is the possibility that state challenges may so engulf the industry in complex intergovernmental legal problems that the use of nuclear fuels for electrical generation will not increase significantly.

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[3] For discussion, see Boyd R. Keenan, Ohio Basin Interstate Energy Options: Constraints of Federalism (ORBES Phase II).

Nuclear Waste Disposal. The problem of nuclear waste disposal highlights the issues that surround the preemption doctrine.[4] By their nature, nuclear wastes probably will remain at their disposal sites forever, at least in terms of human time. Moreover, even if no additional nuclear-fueled generating units are built, other activities such as military defense operations and medical diagnostic and treatment processes will continue to produce radioactive wastes. Finally, waste disposal sites appear to bring no advantages to the local community to offset their inherent dangers, except a relatively small number of jobs.

The Atomic Energy Act established a regulatory scheme that gave all authority over the disposal and storage of nuclear wastes to the Atomic Energy Commission and, subsequently, the Nuclear Regulatory Commission (NRC). In 1959, amendments to the Atomic Energy Act gave the states limited control over the disposition of certain nuclear wastes through individual agreements between a state and the federal government. However, regulations do not allow an "agreement" state to assume regulatory authority for the disposal of high-level wastes, such as spent fuel rods. In addition, agreement states do not have regulatory authority over either the storage and handling of radioactive wastes at a nuclear generating facility site or the discharge of effluents from the site.

The provisions of the Atomic Energy Act were addressed further in February 1980, when the President announced a "comprehensive plan for burying the nation's radioactive nuclear wastes" at permanent sites by the mid-1990s. Some utilities already are running out of temporary storage space near reactors. Thus, the President asked Congress to authorize, in the interim, the building or purchase of one or more "away-from-reactor" sites where utilities could store spent fuel on a temporary basis for up to 30 years. It is hoped that at least one such site will be ready for use by 1985 or 1986.

In seeking to avoid the kind of future institutional barriers discussed in this section, the President announced that he intended to create by executive order a council of governors and other officials. The council's charge would be to overcome the local problem of disposal site selection. However, a state would not have the power to veto a site once the "consultation and concurrence" process is finished. Debate within Congress and elsewhere over what is meant by "consultation and concurrence" is a further illustration of the conflict over federal preemption and raises additional questions on whether the Supreme Court will uphold the doctrine. This debate also points up the improbability of an increasing reliance on nuclear fuel.

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[4] See Keenan, Ohio Basin Interstate Energy Options.

The administration's announcement that it is seeking to build or buy one or more interim sites for storing spent fuel rods touched off controversy in the Illinois portion of the ORBES region; Illinois was mentioned as one of three states from which the site would be selected. State political leaders expressed concern that the President already had decided to deposit fuel rods from throughout the United States and several foreign countries at a facility in Morris, Illinois, 65 miles southwest of Chicago, in the extreme northern portion of the ORBES region. Depending on the final interpretation of "consultation and concurrence" in light of the Atomic Energy Act provisions related to waste disposal, a decision to acquire the Morris site could be made totally at the national level.

It is clear that any greater reliance on nuclear power in the ORBES region and elsewhere would depend on reforms in the management of nuclear waste that are acceptable to the sectors involved, including the general public, the utility industry, and federal, state, and local governments. However, reform proposals now being offered are contradictory and not likely to result in consensus. For example, a recent NRC task force specifically rejected the desirability of allowing states to regulate nuclear wastes. It recommended that the federal government take over and establish a perpetual care program. On the other hand, members of Congress have urged reconsideration of whether preemption should apply to nuclear waste management and disposal.

In the abstract, most Americans probably would agree that federal action to preempt local land use control decisions from state and local governments, particularly when the land use might involve serious health risks, is undesirable and a break from traditional values associated with the federal system. However, most of the public probably also would agree that decisions on defense, international trade, and major economic matters, and now even major energy decisions, are best made at the national level. Thus, it may be necessary to determine whether the nuclear facility siting and regulation question is primarily one of local land use and health hazard control or primarily one of defense, trade, economics, and energy. However, so many sensitivities and sub-issues are associated with this choice that it probably will not be made soon. If the courts continue to construe the Atomic Energy Act as giving almost exclusive control over nuclear facilities to the federal government, then the question remains with Congress. The resolution will depend on the strength of states' rights feelings, public fears of nuclear hazards, the dimensions of the energy crisis, international trade, the stability of the dollar, and domestic economics.

COMPARATIVE COAL AND NUCLEAR COSTS. A second factor that could influence the future of nuclear power is pointed up by an ORBES inquiry into the comparative costs and associated electricity prices for coal-fired generation compared with nuclear-fueled generation.[5] One key finding is that, under the current fiscal and regulatory schemes prevalent in the ORBES region, coal-fired units have a slight cost advantage over nuclear-fueled units. Perhaps even more significant for future energy policy and development is another key finding: without present federal tax and other fiscal policies that favor capital-intensive production (including the nuclear industry), the cost advantage of coal-fired over nuclear-fueled generation would be substantially greater. However, regulatory environments, tax and subsidy provisions, and fuel and other costs vary across states as well as within a given state. Therefore, no set of results for a particular area necessarily applies to the region in general.

Representative utilities in southern Indiana, an area thought to reasonably exemplify conditions throughout the ORBES region, were chosen for the analysis. The study focused on the choice by the utility between coal-fired and nuclear-fueled electrical generating capacity in the context of specified economic tax and regulatory conditions. Nuclear-fueled capacity has been widely believed to be less costly than coal-fired capacity for electric utilities as well as for the consumer of electrical energy. (Standard industry studies suggest that coal-fired electrical generation is about 16 to 20 percent more expensive than nuclear generation.) This conclusion was examined in the representative portion of the study region.

Two primary methods of electric pricing were considered: (1) the constant real price, which escalates base price for overall inflation rates, and (2) the rate base price, which is determined by conventional regulatory methods where rate base return to capital and fuel and operating expenses figure into price determination. Using constant real price, both nuclear-fueled and coal-fired facility costs would rise by approximately 7 percent per year, suggesting real 1988 dollar costs that are quite similar: 7.33 cents per kilowatt hour for nuclear and 6.3 cents per kilowatt hour for coal. In 1977 dollars, nuclear and coal facility costs would be 3.5 cents per kilowatt hour and 3.0 cents per kilowatt hour, respectively. Therefore, with existing subsidies, the conventional after-tax costs to utilities are higher for nuclear-fueled than for coal-fired generating units. Nuclear capacity, then, is not less costly than coal in this representative case.

Tax Subsidies. An important consideration when assessing utility costs and electric prices is the presence of tax subsidies at both the state and the federal levels, which affect comparative costs as well as prices of nuclear-fueled and coal-fired generation. If adjustments are made in the tax structure so as to remove major deductions and credits (which constitute subsidies) from the corporate income tax structure, nuclear costs rise to 11 cents per kilowatt hour, compared with coal costs of 7.6 cents per kilowatt hour (1988 dollars). Thus, within the present corporate income tax structure, nuclear-generated electricity is slightly more expensive than coal-generated electricity. When tax subsidies are excluded, however, nuclear power appears to be considerably more expensive. In particular, the subsidy received by a representative nuclear unit is almost three times greater than that received by a representative coal unit (for a 1000 megawatt unit, in 1988 dollars, $201 million and $68 million, respectively). The explanation for the magnitude of this difference in tax subsidies lies in the different capital intensities of the two processes. In 1988 dollars, the representative nuclear unit has a rate base investment of $3238 per kilowatt at the beginning of operation in 1988. The representative coal unit has a rate base investment of $1364 per kilowatt in 1988 dollars at the beginning of its operation in 1984.

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[5] See Duane Chapman, Kathleen Cole, and Michael Slott, Energy Production and Residential Heating: Taxation, Subsidies, and Comparative Costs (ORBES Phase II).

Utility planning also is influenced by the timing of net income tax liability and flow of funds. Particular patterns with respect to time may encourage or discourage the early retirement of generating units. Using the rate base pricing method, which simulates actual regulatory behavior, the overall effect of the interaction of regulatory procedures, tax provisions, and net income accounting is to create a financial incentive for premature construction of new plants as well as premature retirement of old ones.

Inflation and Interest Rates. General inflation and interest rates also are important when considering subsidies to nuclear-fueled and coal-fired units. These rates also are important for the price of electricity. All of the above conclusions are based on a 7 percent inflation rate and a 9.5 percent interest rate. Because of the difference in capital intensity between nuclear-fueled and coal-fired units, higher inflation and interest rates could change these conclusions. Assuming an inflation rate of 12 percent and an interest rate of 14.5 percent, and including existing tax subsidies, nuclear-fueled generating costs in 1988 dollars would be 11.1 cents per kilowatt hour, while coal-fired generating costs would be 9.3 cents per kilowatt hour. Without subsidies, nuclear costs would be 18.9 cents per kilowatt hour; coal costs, 11.3 cents per kilowatt hour. The tax subsidy on nuclear-fueled generation, then, would amount to 7.8 cents per kilowatt hour; that on coal-fired generation, to 2 cents per kilowatt hour. Thus, the slight advantage of coal-generated electricity rises with higher inflation and interest rates.

Research and Development Subsidies. Among the major federal subsidies of nuclear-fueled generation is extensive government research and development in the nuclear field. These activities have been significant in the past 40 years and have far exceeded public funds devoted to research on coal and on coal-fired electrical generating processes during the period. Although national defense has been the principal consideration of the federal government in subsidizing the nuclear research, the resulting information and innovations have tended to decrease the costs and raise the profits of private nuclear developers.

Price-Anderson Act. Another federal subsidy that should be mentioned is provided by the Price-Anderson Act, which was passed by Congress in 1957 to limit the aggregate liability for a single "nuclear incident" to $560 million. The federal government is directed to subsidize the liability insurance premiums of private nuclear developers, a subsidy not extended to coal producers and their utility consumers. The announced purpose of the subsidy under the act, which applies to insurance coverage over $1 million, is to encourage nuclear development.

15.2 Alternative Fuels

In this section, the emphasis is on institutional issues associated with the use of direct and indirect solar energy processes for electrical generation: solar energy (section 15.2.1), wind energy (15.2.2), and biomass (section 15.2.3). The processes themselves are described briefly in chapter 13.

15.2.1 Solar Energy

The widespread adoption of solar energy as a substitution fuel for coal would have major effects in the ORBES region. Although much of the necessary technology is available or close to available (see chapter 13), a series of economic and institutional barriers would have to be overcome. The institutional issues associated with the introduction of solar energy can be divided into three groups: legal and physical access to sunlight, integration with existing energy infrastructures and institutions, and government program implementation and management.

SOLAR ACCESS. Problems surrounding legal and physical access to sunlight constitute a significant barrier to the widespread introduction of solar energy.[6] This barrier, which stems from the basic orientation of real property law toward the development of land, confronts almost any potential solar energy system investor. In general, the investor is not guaranteed permanent access to sunlight. Unless assured of such access, the investor will be reluctant to install a solar system, even though tax incentives and the costs of other energy sources do much to compensate for the large initial investment required for solar equipment. Thus, the investor must be concerned not only with the unique climatic and geographic factors that influence site location, but also with what is or will be located on adjacent property.

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[6] For a complete discussion of access to sunlight, see Vincent P. Cardi, Larry Harless, and Thomas Sweet, Legal and Institutional Issues in the Ohio River Basin Energy Study Region (ORBES Phase II).

As elsewhere in the United States, the owner of a solar collector in the six ORBES states usually is without legal remedy when his access to sunlight is blocked. This situation exists because decisions based on U.S. common law have not established a legal right to access to sunlight. The basis is an ancient doctrine that allows a person to build any structure on land he owns; legally nothing can be done to prevent it, whether the structure blocks sunlight or not.

Through the centuries, however, slight modifications have been made to this absolute right. Under the doctrine of ancient lights, promulgated in 1610, an English court held that if a landowner has received light from across a neighbor's land for a certain period of time, the right to enjoy this light continues. This doctrine was rejected early in American history on the grounds that it could not be applied in the growing cities and that its application would hinder the development of property.

Nuisance Law. Application of the nuisance concept is a possible way in which legal access to light might be ensured. To prove a private nuisance, or a "nontresspatory invasion of another's use and interest in the private use and enjoyment of land," one must show (1) intentional or negligent interference with the use and enjoyment of property, (2) the unreasonableness of such interference, and (3) substantial harm. The major issue in a private nuisance action involving solar access may be the reasonableness of the interference. In the past, courts have ruled for land development over energy development, but some legal scholars feel that a case can be made for energy development to take precedence. However, the use of private nuisance as a means of ensuring access to sunlight has been criticized severely; some claim that the very nature of a private nuisance action, balancing competing interests of landowners, hinders its effectiveness.

In contrast to a private nuisance, a public nuisance affects an interest common to the general public, rather than an interest of only one or a few individuals. Thus, for an interference with solar access to be declared a public nuisance and a valid area for exercise of the police power of the state, it actually must affect the public interest. The present energy situation might mandate a public interest in the development of alternative energy sources, such as residential solar energy systems. Perhaps it could be argued successfully that the preservation of the community is at stake in providing alternative sources of energy and hence that alternative energy development falls within the guidelines of the police power. Since shadows were not a public nuisance under the common law, enactment of legislation would be necessary to have interference with access to sunlight legally defined as a public nuisance. Most state legislatures appear unwilling to take this step; one exception is in California (Cal. Pub. Res. Code, sec. 25982 (Deering)).

Zoning. The police power of the state as expressed in zoning also could be applied to solar access. The legal power to zone, which is derived from the police power and usually is delegated to local governments, exists in all 50 states. The purpose of a solar zoning ordinance, of course, would be to encourage utilization of solar energy for the heating and cooling of buildings and to reduce consumption of and dependence on fossil fuels. Unquestionably this purpose relates to the general welfare and health of people and the state. It follows, then, that the enactment of such an ordinance could be a legitimate exercise of the police power.

Zoning can take the external benefits of solar energy into account, so that society as a whole pays for the higher quality environment made possible by individual investments in solar energy devices. The main advantage of zoning would be uniformity of application: the burden of bringing suit is not on the individual user, and an immediate right to solar access is vested in each individual. A major disadvantage of this approach would be the political machinations that are inherent in local zoning schemes. Present zoning ordinances and building codes in themselves also present problems, because in many cases they impede private investment in solar energy installations. For example, solar permits have been denied for failure to comply with ordinances that restrict the total area of mechanical equipment to a certain percentage of the area of the supporting roof.

Solar Easements and Restrictive Covenants. Two other approaches, the solar easement and the restrictive covenant, also should be noted. The solar easement is a variation of the property easement, which is an interest in land that is in the possession of another party and which gives the owner of the easement an interest in or limited enjoyment of that land. Most simply, the solar easement usually obtained by a solar investor is a device to gain airspace above the property of a neighbor. However, solar easements are complicated and must be expressed clearly in legal terms; they cannot be created by implication. Costs could be the major problem with the easement approach. To ensure total solar access, easements would have to be obtained over all property that could possibly be developed so as to block access. Thus, the cost of obtaining these easements might be greater than the value of switching to a solar energy system. This is almost certain to be the case in densely populated areas. Also, even though a potential seller of an easement may not plan to construct high buildings or plant trees, he may be reluctant to encumber his property for the future except at a relatively high price. Most legal commentators appear to believe that solar easements alone would be inadequate to ensure continuous access to sunlight, particularly in cities, where airspace is so valuable.

The restrictive covenant often is used by property developers to assure homogeneity and aesthetic qualities deemed necessary to attract investors. Many covenants are used to control the changes that the purchaser of a developed lot can make in his property after buying it. (Although covenants can be used to protect solar access, they also can prevent installation of a solar collector on aesthetic grounds.) A "solar covenant" would assure the solar investor that no structure would block the flow of sunshine across adjacent property and shadow the collector.

The transition to protection of solar access through restrictive covenants would not seem to be particularly difficult. The use of such covenants to prevent solar collector installation was held to be invalid in a recent California case (Kraye v. Old Orchard Association, no. C209453, L.A.S.Ct., March 1, 1979). Recognizing a statewide policy to conserve nonrenewable fossil fuels and encourage the use of alternative energy sources, the court held restrictive covenants to be "invalid and unenforceable to the extent that they prohibit the rooftop installation of solar collector plates." Solar covenants could be important tools in the development of solar energy use in new developments, but they would provide no remedy to the solar investor in an existing neighborhood.

State Legislation. Finally, as in California, Colorado, and Oregon, state legislatures could act on the solar access measures described above.[7] Only two ORBES states, Illinois and Ohio, have enacted such legislation; both laws are limited. The Illinois Comprehensive Solar Energy Act (Ill. Ann. Stat., ch. 96-1/2, sec. 7301 et seq.), which became effective in 1977, declares that it is in the public interest to define solar energy systems, demonstrate solar energy feasibility, apply incentives for using solar energy, educate the public on solar feasibility, study solar energy applications, and coordinate governmental programs affecting solar energy. More important, it creates a "solar skyspace easement," a concept introduced in this piece of legislation, but a rather indirect approach to the problem. The statute fails to provide for (1) tracing collectors and greenhouses that can use sunlight at times of day other than those specified in the act, (2) specific conditions where an easement is to be granted, and (3) tax incentives or exemptions. Nevertheless, it is a step toward ensuring solar access. The Ohio statute, which became effective in 1979, recognizes solar easements and prescribes their contents (Ohio Rev. Code, secs. 1551.20, 4933.32, 5301.63, and 5709.53). However, this law does little more than recognize solar easements. It makes no attempt to mandate them or to define them further.

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[7] For a summary of solar access laws, see "Access to Sunlight: the Legislative Response," Solar Law Reporter 1 (1979):110-21.

INTEGRATION WITH EXISTING SYSTEMS. In addition to solar access, the integration of solar energy systems into existing energy infrastructures and institutions presents a series of legal and institutional issues. Among the problem areas are (1) the rates paid by utilities for power sold to the grid as well as for back-up power and other services provided to on-site generators, (2) the legal status of on-site generators, (3) the financing and ownership of dispersed capacity, and (4) utility management issues and perceived risks.

Utility Interconnections. Prior to the National Energy Act of 1978, there were three major obstacles faced by on-site solar electricity generators seeking to establish interconnected operation with a utility. First, utilities usually were not required to purchase electric output at an appropriate rate. Second, some utilities charged extremely high rates for back-up service to on-site generators; the reasoning was that this service would increase capacity reserve requirements and thus the incremental cost of providing power to all customers. Third, an on-site generator that provided electricity to a utility grid, or sold any of the excess power generated to anyone else (such as a neighborhood association or cooperative apartment selling to its members or residents), ran the risk of being considered an electric utility and, as such, subject to state and federal regulation.

Sections 201 and 210 of the Public Utility Regulatory Policies Act (PURPA) of 1978 (16 U.S.C. 2601 et seq.), part of the National Energy Act, are designed to remove these obstacles.[8] Under section 210 of PURPA, each electric utility is required to offer to purchase available electric energy from on-site generators that obtain qualifying status under section 201 of the act. For such purposes, electric utilities are required to pay rates that are just and reasonable to the ratepayers of the utility, that are in the public interest, and that do not discriminate against on-site generators. These rates must reflect the cost that the purchasing utility can avoid as a result of obtaining energy and capacity from these sources rather than generating an equivalent amount of energy itself or purchasing the energy or capacity from other suppliers. In addition, utilities must provide certain other types of service that may be requested by on-site generators to supplement or back up their own facilities. Finally, the Federal Energy Regulatory Commission can exempt on-site generators from state regulation regarding utility rates and financial organization, from federal regulation under the Federal Power Act (other than licensing under Part I), and from the Public Utility Holding Company Act.

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[8] See Federal Register 45 (February 25, 1980):12214.

Financing and Ownership. A number of issues have been raised about the financing and ownership of dispersed electric generating capacity, including solar systems.[9] On the one hand, it is argued that the potential for unfair competition supports a complete prohibition of utility involvement in such matters as financing and supplying on-site generators. Those who support this view argue that the substantial utility investment in conventional generating equipment will make it in their interest to restrict competitive energy sources rather than promote them. In addition, utilities could use their financial strength to drive smaller rivals out of business. Even if utilities actively seek to use on-site capacity resources rather than stifle them, business advantages from dealing with utilities could make it too difficult for other entities to compete or for emerging technologies to gain a place in the market. It is exactly these concerns related to unfair competition that led to the prohibition in the National Energy Conservation Policy Act (NECPA) (P.L. 95-619, codified in sections of titles 12, 15, 23, and 42 of the U.S. Code) of utility involvement in supplying, installing, or financing residential energy conservation measures, including solar and wind generators. Individual utilities may get a waiver from this NECPA prohibition if they can demonstrate that "fair and reasonable prices and rates of interest would be charged. . . and that such activities would not be inconsistent with the prevention of unfair methods of competition and the prevention of unfair or deceptive acts or practices" (sec. 216).

On the other hand, it has been argued that homeowners and others interested in on-site generation do not have the access to capital markets and financing mechanisms that utilities do, and that without utility participation initial investment costs will be prohibitive. Moreover, many utilities now desire to diversify their capacity and those that want to enter the market would not be able to do so. If the NEPCA prohibition did not exist, utilities would have to raise several times less capital than for central station capacity. This money could be turned over at least twice as quickly. Thus, the utilities would retain their attractive rate of return on capital.[10] However, utilities would have to be allowed to include the financing, supplying, and installing of on-site generation equipment in their rate base. It is probable that the close scrutiny of utility promotional and other activities that has been commonplace since the 1960s would provide sufficient checks against unfair competition or stifling of the expansion of on-site generation.

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[9] For discussion, see William H. Lawrence and John H. Minan, "The Competitive Aspects of Utility Participation in Solar Development," Indiana Law Journal 54 (1978-79):229.

[10] Amory B. Lovins, "Energy Strategy: The Road Not Taken?," Foreign Affairs (October 1976), pp. 87-88.

Utility Management. Another problem related to integration of on-site generators with existing energy systems, mainly utilities, is that current utility management and other infrastructures are designed around central station capacity. Management techniques would have to change to accommodate a transition to dispersed capacity, including perception of risks by management.

GOVERNMENT PROGRAMS. The final set of institutional issues related to solar energy has to do with the management of government solar programs. A recent study done for Congress has identified a number of deficiencies within the Department of Energy's Conservation and Solar Energy Programs (CSE) that are retarding the development and deployment of solar energy.[11] First, the internal DOE organizational structure, including the responsibility for solar energy, changes so frequently that jurisdictional disputes and uncertainty seriously detract from the real business of CSE. Second, according to the study, CSE lacks a clear vision of where it is going and how it will get there. Evidently, this deficiency results from a lack of clear direction from DOE management and the lack of a strong analytic capability within CSE. There is a pervasive belief within and outside of DOE that senior agency management has been inadequate as well as transient. This is compounded by long delays (sometimes up to 18 months) in DOE processing of CSE requests for hiring new staff and letting contracts. Another conclusion is that there could be improved coordination between CSE and other federal agencies responsible for solar energy as well as with state and local governments.

State and local programs designed to promote solar energy vary widely. Some, such as those of the state of California and its cities of Los Angeles and San Diego, either mandate or actively encourage the use of solar in new construction and in retrofitting activities. These programs include low-interest loans, zoning codes that require solar hot water in all new houses, active information dissemination and technical assistance, and other aggressive measures.

15.2.2 Wind Energy Conversion Systems

Wind energy conversion systems (WECS) have been in use for many centuries, traditionally for irrigation and milling operations. As long as 400 years ago, windmills in the Netherlands were used in the production of paper and the processing of timber. Since the early 1900s, wind energy systems also have been used to generate electric power. Prior to World War II, over 6 million small windmills had been built in the United States; most were used in rural areas to pump water and produce electricity. In general, these were small systems, ranging in output from a few watts to a few kilowatts. The notable exception was the 1.25 megawatt Smith-Putnam wind turbine located at Grandpa's Knob, Vermont, which fed power into the local grid from 1943 until April 1945. A number of intermediate-sized units were tested in Europe from the 1930s through the 1950s. However, the vast majority of windmills in the United States have fallen into disuse due to the advent of cheap fossil fuels and the provision of inexpensive and reliable power from the rural electrification program. Recently, as oil prices have climbed and the environmental risks of nuclear and fossil fuels have been perceived, interest in wind energy has risen sharply.

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[11] U.S. Congress, Office of Technology Assessment, Conservation and Solar Energy Programs of the Department of Energy: A Critique (OTA-E-120, June 1980).

Large-scale systems (over 1 megawatt) are expected to compete first with utilities that depend heavily on oil and also in areas with a large hydroelectric capability, where the conventional system can serve as a backup. As a result of the cost reductions for wind turbines through mass production and advanced design, the use of WECS is expected to increase.

DOE has established an energy cost goal of 3 to 4 cents per kilowatt hour (1980 dollars) for both small and large WECS. This goal is a levelized life-cycle energy cost. It is anticipated that an initial market will begin to form when the cost is about 4 to 7 cents per kilowatt hour, a level sufficient to support the production of early systems in moderate quantities.

As with other solar and dispersed electric energy systems, the widespread introduction of WECS raises a number of legal and institutional issues. These include financing, siting, tort liability, and environmental problems.[12] Issues related to interconnection with utilities are discussed in section 15.2.1.

FINANCING. Although cost effective over the long run in most circumstances, present wind energy technologies, both small- and large-scale, have relatively high initial investment costs. This problem is heightened because WECS are a new technology, and the financial institutions that control most of the money used for such projects tend to be conservative in backing new technologies. Therefore, financial incentives from the government and the private sector might accelerate the introduction of WECS. Issues related to utility financing are discussed in section 15.2.1.

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[12] See Lynde Coit, Wind Energy: Legal Issues and Institutional Barriers (SERI/TR-62-241, June 1979), and Cardi, Harless, and Sweet, Legal and Institutional Issues.

A number of states provide income tax deductions and credits that apply to wind systems. Under the Energy Tax Act of 1978 (P.L. 95-618), part of the National Energy Act, the federal government allows tax credits for homeowners and businesses. The residential energy credit provided under Title I of the Energy Tax Act applies to "wind energy for nonbusiness residential purposes," while Title II provides a business investment tax credit "to encourage new energy technology." The availability of these credits should spur homeowners, utilities, and industry to consider wind energy generation.

ZONING AND BUILDING CODES. In addition to access to wind, the siting of WECS raises issues related to zoning and building codes. As discussed in section 15.2.1, zoning is the most pervasive form of land use control in the United States. All states have enabling legislation for zoning, and most communities with more than 5000 inhabitants have enacted zoning ordinances. The typical ordinance provides for areas restricted to residential, commercial, and general industrial uses. Because almost any use is permitted in an industrial area, WECS should meet no zoning problems there. It is in residential and commercial areas that problems are most likely to arise. The most probable challenges to wind machines will be on aesthetic grounds, or because they violate height restrictions, or because they are not an "approved use" for the area. However, the main zoning issue for small machines is public acceptance; in the absence of objections by homeowners and tenants, variances may be obtained from other provisions that limit their use. Larger WECS should encounter fewer problems with zoning ordinances, primarily because they are more likely to be sited in rural areas. However, if the total capacity of all the machines at any one site is greater than 80 megawatts, the siting provisions of state public utility commissions may apply.

WECS in urban areas also will be subject to building code requirements. At present, the primary obstacle is the lack of a general consensus on what a wind-oriented building code should be, due to the lack of data on wind turbine performance under a variety of conditions. A set of interim performance standards could be developed that emphasize fire safety, structural soundness of the tower, ability to withstand the strongest foreseeable wind, and conformity with standards for electrical work. In the absence of state action in this area, it is likely that wind-oriented building codes will be preempted by the federal government, as is the case for mobile homes and energy performance standards for buildings.

WIND ACCESS. The legal issue surrounding guaranteed access to the wind does not involve conflicts with existing laws, as in zoning, but rather the lack of any legal doctrine assuring a wind machine owner continued access to unimpeded wind flow over his property. The problem is significant because wind power varies directly with the cube of velocity. This means that by reducing the wind speed by one-half, the energy that can be generated is reduced to one-eighth its original amount. Even a seemingly slight reduction in wind speed from 10 miles to 8 miles an hour results in a 50 percent reduction from the energy originally available. This reduction may be sufficient to shut some machines down entirely, depending on the "kick-in" speed, or to make them no longer cost effective. Large-scale WECS developers probably will want to locate in remote areas far from any obstructions and to purchase sufficient land to guarantee their wind flow. However, purchase of surrounding land may be prohibitively expensive for small users and may be impossible in urban areas.

Small users may be able to acquire negative easements over the property of adjoining landowners, similar to the easements for solar access discussed in section 15.2.1. With a negative eastment, the WECS owner could purchase the legal right to prevent the adjoining landowners from obstructing wind flow. However, these rights probably would have to be purchased in several directions, and where they reduce the development potential of the adjoining land, and thus its value, they also could be extremely expensive. It is more likely that statutory rights to wind access would be created by legislatures, but the form of such legislation is problematic in most developed areas.

TORT LIABILITY. The issue of tort liability related to wind machines is essentially a question of their safety. WECS being considered today bear little resemblance to the small, innocuous rural windmills common prior to World War II. Today, machines up to 750 feet high are being proposed, and WECS with "wingspans" of 300 feet are under construction. Understandably, there is concern about the safety of these large systems. In 1945, the Grandpa's Knob machine threw a blade weighing eight tons a distance of 750 feet, the result of a design defect that had not been corrected due to the shortage of steel during World War II. Under "worst case" conditions, a blade could land over 1500 feet from the supporting tower. Another concern is the collapse of a tower. A third situation that could give rise to tort liability is if a workman were injured or killed while working on utility lines during a time when power was shut down to allow repairs, but the WECS continued to feed electricity into the grid.

Ultimately these issues will be resolved by technological improvements in wind turbine systems. During power outages, synchronous inverters will disconnect a WECS automatically. Towers will be reinforced to allow for the stresses placed on them by long and heavy rotors. Moreover, the machines built today all feather their blades in high winds and shut down completely when the wind reaches a certain speed, so that even unusually high winds should not pose problems. In adddtion, the National Aeronautic and Space Administration (NASA) is investigating "fail-safe" systems that would prevent a thrown blade from traveling significant distances from the tower.

However, until these technical fixes are mandated by industry standards, liability will remain a question for manufacturers because they may be liable under consumer products liability law; for potential owners because they may not be able to get insurance; and for neighbors of owners because they are concerned about their property and personal safety. In the case of manufacturing or installation defects, it is likely that the manufacturer will be held liable under either strict liability or negligence. The American Wind Energy Association is concerned that these doctrines might frighten prospective manufacturers and retailers out of the market, and the association is lobbying for a federally imposed limit on liability similar to that in the Price-Anderson Act for nuclear plants (see section 15.1). An alternative solution might be some form of government-funded product liability insurance for WECS manufacturers, retailers, and users whose products meet certain standards. On the other hand, if standards are developed, conforming machines are publicized widely, and private sector insurance becomes available for these machines, it is unlikely that a legislative approach will be necessary.

ENVIRONMENTAL QUESTIONS. Finally, WECS are not free from environmental problems. The rotating metal blades can produce video distortion of television reception, especially on the upper ultrahigh frequency channels and where the wind machine is directly between the broadcaster and the receiving antenna. This distortion can be avoided in part by the use of nonmetal blades or by proper siting. Courts have held that landowners have no right to uninterrupted television reception (People ex rel. Hoogasian v. Sears, Roebuck Co., 52 Ill.2d 301, 287 N.E.2d 677 (1972), cert. den. 409 U.S. 1001). With large arrays of wind machines, such as those proposed for utility use, the owner could construct a relay station for the radio waves and thus circumvent the problem. Although the possibility of weather modification and noise problems from WECS has been raised, these problems are not expected to occur, or, in the case of noise, are subject to simple technical fixes. Similarly, most migratory birds fly too high to be killed by rotating blades, and bird kills probably will be a problem only when endangered species are involved, which is a siting issue. The most significant adverse environmental impact of WECS is likely to be aesthetics. Without legislative or judicial intervention in the public interest to promote renewable energy sources, aesthetic objections alone may be sufficient to keep WECS out of zoned areas. However, if WECS are sited so as to minimize their adverse aesthetic impact, they probably will be accepted in the public interest, as power lines and other similar structures have been.

With the exception of financing and utility integration issues, most of the problems discussed above are likely to be minimal once the public becomes used to WECS and realizes their value as a domestic, renewable energy source.

15.2.3 Biomass

The biomass fuels and conversion processes outlined in chapter 13 either are in present use in the United States or could become commercial in the next

5 to 10 years. In addition, their prices probably will be competitive with that of imported oil. A number of other bioenergy sources are considered promising, but none is expected to contribute significantly to U.S. energy supplies for at least 20 years. Among these unconventional sources are saltwater and freshwater algae and other plants (mariculture and aquaculture), land-based oil and hydrocarbon crops (such as eucalyptus, guayule, euphorbia, jojoba, and milkweed), and the intensive cultivation of plants for energy purposes on tree farms and other "energy plantations."

The ORBES region is rich in biomass resources. As discussed in section 4.4, forest areas cover 31 percent of the region. Among the state portions, the proportion ranges from 69 percent in West Virginia to 10 percent in Illinois. Three of the state portions--Illinois, Indiana, and Ohio--have a high proportion of cropland to total land area (from 71 to 57 percent). These three states are among the five highest ranking states with crop residues usable for energy. The potential for additional grass production for energy uses is high in Kentucky, while Illinois, Indiana, Ohio, and Pennsylvania have average potential.

ADVANTAGES. There are advantages and disadvantages common to all forms of biomass energy.[13] A major advantage is that, when managed properly, biomass resources are renewable. Moreover, these resources are domestic and thus can reduce U.S. dependence on imported oil. In fact, biomass can contribute to energy self-sufficiency in certain sectors, including municipalities, agriculture, and the forest product industries. With regard to the environment, biomass conversion tends to be less polluting than conventional fuels. Thus, biomass use could help solve pollution and waste disposal problems. Finally, depending on the technologies adopted and the scale of production, bioenergy may provide the basis for the growth of small businesses and the decentralization of economic activity, both of which are valued by many Americans.

DISADVANTAGES. Among the disadvantages of biomass fuels (especially wood and starch and sugar crops) is that they already have established nonenergy uses that could compete with new uses for energy. Also, many biomass technologies produce energy in a quantity, quality, or form that is not easy to match with existing energy distribution or consumption systems. Many of the existing small-scale conversion technologies require individual labor for continuous operation. Thus, these technologies are less convenient than conventional technologies. It also should be noted that the harvesting of biomass resources in logging and agriculture could lead to a higher incidence of occupational injury than the extraction of conventional fossil fuels, including coal mining.

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[13] See U.S. Congress, Office of Technology Assessment, Energy from Biological Processes (OTA-E-124, July 1980).

The widespread introduction of bioenergy raises a number of institutional issues. Those common to all bioenergy sources are discussed first. In general, these institutional problems fall into two categories: (1) governmental response and (2) as with solar and wind energy, integration with existing energy infrastructures.[14]

SHARED INSTITUTIONAL ISSUES

Government Programs. A number of measures have been proposed by Congress to promote new energy sources of all kinds, and many of these measures will improve the prospects for bioenergy. However, because of the wide range of biomass feedstocks and conversion technologies, policies carefully tailored to bioenergy would appear to be desirable. For example, programs could be developed to provide information and technical assistance to bioenergy users and to establish reliable supply infrastructures for energy uses of biomass resources. To assure that bioenergy resources will be renewable, there would have to be long-range energy and resource planning and proper resource management in both public and private operations. This long-term need, however, is not met by present political, economic, and energy planning. If the use of biomass for energy is expanded, previously independent economic sectors will become linked. These links could have significant institutional implications for regulation, such as those related to antitrust.

Federal administration of bioenergy research, development, and implementation has been deficient in various ways. Most federal bioenergy programs are understaffed and underfunded; rapid management turnovers are the norm. Where more than one agency has jurisdiction, there tends to be little coordination between them; in some areas, lead responsibilities either are poorly defined or change frequently. Also, as discussed in section 15.2.1, federal programs tend to focus on large central-scale applications, with little support for small users and on-site technologies. Finally, basic resource inventories need to be conducted for all bioenergy sources.

Integration with Existing Energy Infrastructures. Because bioenergy may not be in a quality, form, or quantity that fits conventional energy supply infrastructures or users, institutional changes would have to be made. For example, where biomass is used to produce electricity, provisions must be made to sell surplus electricity to the grid at equitable rates and to supply back-up power to producers of bio-electricity. To some extent this issue has been addressed by the Public Utility Regulatory Policies Act of 1978 (see section 15.2.1), but implementation of PURPA by the states will take several years. Similarly, where biomass produces more methane gas than can be used on the site, either a storage facility or a pipeline linkage must be provided.

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[14] See U.S. Congress, Office of Technology Assessment, Energy from Biological Processes, and Materials and Energy from Municipal Waste (OTA-M-93, July 1979).

In addition to institutional issues associated with all bioenergy sources, other issues are specific to each form of biomass. In general, these questions relate to the regulation of forest lands or agricultural crops, environmental damage, and economic controls.

WOOD. The primary institutional issue related to the use of wood for energy is the management and care of the resource base, that is, forestlands. Wood is an attractive energy source in part because an increase in demand could lead to better forest management, which in turn would increase the quantity and quality of timber available for all uses. However, this is not certain to occur. Also, in the process it may not be possible to avoid the many kinds of environmental damage that can result from wood harvesting, transportation, and conversion. Supportive programs are particularly needed outside the forest products industry, where inexperience with wood harvesting could lead to "mining" of the resource. Fifty-eight percent of the nation's forest land is controlled by 4.5 million private, nonindustrial woodlot owners, and their behavior is unpredictable. Short-term economic incentives tend to favor improper management, and few effective state and federal programs provide incentives for environmentally sound management by these private owners.

The timber available for all uses could be increased in quantity and improved in quality by intensive timber management, but the character of the forests would change. Removing logging residues and increasing stand conversions and thinning would mean more uniform, open forests with a higher proportion of even-age, single-species stands--similar to those in Europe today. Bird, animal, and insect species that depend on dead and dying trees would decline in population, and other species would increase in number. The greatest changes in forest character would occur in flat, easily accessible lands; steep or environmentally vulnerable lands would be affected less because often harvesting is more expensive there. Such changes would not be welcomed by many environmental groups, especially those concerned with preserving natural ecosystems, although other groups concerned with promoting hunting or increased public access might welcome such changes.

AGRICULTURE. The primary institutional issues associated with intensive agricultural production for energy are the integration of energy demand for crops into existing markets and the potential for environmental damage. Grain and sugar feedstocks for ethanol also have food and feed value, and buyers for all three uses would be expected to compete for farm commodities. With an increase in the production of grain-based ethanol, distillers who wish a greater share of the market would have to pay higher feedstock prices. These higher prices make it profitable for farmers to bring additional cropland into production: it is both costlier and riskier to farm currently idle land. Moreover, higher prices for grain and sugar crops also make it profitable for farmers to substitute these crops for those currently produced and to change livestock rations. For example, corn and alfalfa could be planted instead of soybeans, and distillers' grain byproducts could be used instead of corn and soybean meal in animal feed. Moreover, higher commodity prices could reduce foreign demand, thus increasing the supply available to distillers. However, the demand for exports has been rising rapidly; this also could contribute to higher prices. In addition, if distillers' grain is not exported at prices comparable to whole grain or soybean products, distilling grain into ethanol rather than exporting it could increase the U.S. balance of trade deficit. Furthermore, higher prices would reduce the purchasing power of domestic grain and sugar crop consumers. Finally, higher commodity prices would be necessary to increase grain reserves, which constitute a buffer against short-term supply fluctuations.

If the market adjustments noted above lead to greater production of grain-based ethanol with relatively small price increases, then little effect on food prices would be felt. If, however, very large price incentives are required to divert land from existing uses to ethanol feedstocks, then the indirect costs of ethanol production to food consumers could be prohibitively expensive. With appropriate priorities and support for research and development, conversion processes for making alcohol fuels from other feedstocks besides grain and sugar crops probably would become commercial before resulting increases in food prices become severe.

Moreover, if large resource shifts can be accomplished at a relatively small cost, it probably would not be necessary to increase and/or control feedstock production by changes in agricultural programs. Rather, current agricultural policies in conjunction with end use subsidies (for example, the federal excise tax exemption for gasohol) could help increase distillers' share of supplies. This would reduce the need for farm income supports, and the focus of agricultural subsidies could shift to the maintenance of strategic reserves, the preservation of cropland against other agricultural uses and against urbanization, and the control of environmental problems associated with agriculture. The critical issues then would be the size, type, and duration of end use subsidies.

Usual agricultural practices often degrade land quality and pollute surface and ground waters; the two problems are linked closely. For instance, erosion both reduces land productivity and is the major cause of sedimentation in surface waters. Similarly, fertilizers and pesticides build up in the soil, changing its ecology, and then enter aquatic ecosystems through runoff.

Both sedimentation and chemical pollution through runoff are regulated under section 208 of the Clean Water Act, which requires states to develop plans for the control of water pollution from nonpoint sources. Effective implementation, however, has been hampered by such problems as the political sensitivity surrounding any federal involvement in land use planning; a lack of direction in EPA guidelines for determining which sources of nonpoint pollution to control, as well as the degree of this control; and short deadlines for the development of new and controversial land use management techniques. As a consequence, the control of nonpoint pollution has received less emphasis in funding to carry out the Clean Water Act than has the control of more immediate and better understood water pollution problems with strict statutory control deadlines, such as sewage treatment and industrial process controls. Future implementation of section 208 is expected to focus more on regulatory, statewide nonpoint source controls. However, given the traditional resistance to regulatory controls by farmers, the low priority assigned to environmental problems of agriculture by both state and federal agencies, and other constraints, it is unclear whether future implementation of section 208 will be any more effective than it has been in the past.

Thus, if set-aside and other potential croplands are brought into production for energy crops, the effects on water pollution could be substantial. In general, these lands have a higher potential for erosion than does land now under production. Therefore, they are more likely to contribute to sedimentation of surface waters. Also, potential croplands may not be as productive, requiring increased use of fertilizers and pesticides that contribute to chemical water pollution. A complicating factor is that any controls introduced could not be tied to energy crops alone, because farmers could shift those crops to their least sensitive lands. Thus, environmental control policies would have to be introduced throughout the agricultural system.

MUNICIPAL SOLID WASTES. The primary institutional issues associated with the use of municipal solid wastes (MSW) for energy relate to the removal of barriers to resource recovery. Materials can be recovered from MSW for recycling in two ways: by collecting wastes that have been kept separate as they are generated (known as source separation) and by separating mixed wastes in a central facility (known as centralized waste recovery). Either method saves energy because less energy is used in the manufacture of products from recovered materials than from virgin raw materials. Only from centralized resource recovery, however, can energy be recovered as fuel.

There are a number of technologies at various stages of development for burning the combustible portion of MSW or for converting it to solid, liquid, or gaseous fuels. However, the only methods now in commercial operation are waterwall combustion, small-scale modular incineration to produce steam, and the production of refuse-derived fuel by wet and dry processes. The most economical approach may be for capital-intensive, centralized facilities to operate in conjunction with separate collection programs. Federal programs could encourage such integration.

Because revenues, most from the sale of energy, are expected to be insufficient to cover the costs of centralized resource recovery plants, a charge for waste disposal must be made. These charges are expected to be from about 50 to 100 percent higher per ton than charges for waste disposal at landfills. Thus, centralized recovery has the greatest potential where both landfill costs and energy prices are high, as in the urban Northeast.

The federal role in research and development on centralized resource recovery is expected to be most effective in the identification, evaluation, and control of environmental and occupational problems; in the characterization of materials; in the funding of basic studies of processes for size reduction, materials separation, combustion, and chemical reaction; and in exploratory design--especially of small-scale systems. Remaining technical problems probably can be dealt with most effectively in the private sector during the course of commercial development.

15.3 Conservation

Energy conservation can be achieved in a variety of ways, including improved lighting and heating efficiencies, insulation, tax incentives, and changes in personal lifestyle. For purposes of ORBES, however, use of only one conservation measure--cogeneration--was quantified for use in a scenario.[15]

COGENERATION. As discussed in chapter 13, cogeneration is the combined production of power, either mechanical or electrical, and of useful thermal energy such as process steam.[16] There are three principal institutional considerations associated with cogeneration: economic factors, environmental impacts, and regulatory constraints. Of these, economics is the most significant. Industrial companies have indicated that the economic rate of return on investment is their single most important criterion for making investment decisions. The major factors affecting rate of return on investment include capital costs and availablility and the anticipated cost savings. The most important cost consideration is the savings realized from cogeneration when compared with the alternative costs of separate operations for in-house steam production and purchased electricity.

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[15] A number of energy conservation measures are discussed in Cardi, Harless, and Sweet, Legal and Institutional Issues.

[16] The information on cogeneration is taken from two sources: Robert Stobaugh and Daniel Yergin, eds., Energy Future (New York: Random House, 1979), and U.S. Comptroller General, Industrial Cogeneration--What It Is, How It Works, Its Potential (EMD-80-7, April 29, 1980).

Another important institutional issue concerning cogeneration is the effect it may have on the environment, especially on air quality. Due to the inability of steam to travel long distances, cogeneration facilities must be located near industry. Therefore, at certain locations there could be increases in pollutant emissions; the analysis of specific cases must be based on both current conditions and on federal and state environmental regulations. For the nation as a whole, however, increased cogeneration should have a favorable environmental impact. Depending on which fuel is used, the higher fuel economy per unit of electricity will bring a corresponding reduction in pollutant emissions from the reduction in generation by electric utilities.

Regulatory considerations center around the reluctance of industry to become involved in what is considered a highly regulated and capital-intensive activity, the generation of electricity. Another industry concern is government regulations that could require plants to deliver cogenerated electricity to the grid to meet utility reserve or emergency capability, thus jeopardizing industrial plant operations. However, as discussed in section 15.2.1, under the Public Utility Regulatory Policies Act of 1978, the Federal Energy Regulatory Commission can exempt on-site generators from certain state and federal requirements.

CONCLUDING NOTE

It is clear why a unit of the U.S. Congress directed the Environmental Protection Agency to carry out the Ohio River Basin Energy Study. A group of citizens had discovered in 1974 that no private or public entity was responsible for coordinating the location of new power plants in their part of the Ohio River valley. They wanted to know why this condition existed and what might be done about it. As EPA pursued its congressional mandate to come up with answers, agency officials decided that the energy and environmental problems stimulating the concerns of this group represented only some of the issues centered around power plants in the broad Ohio Basin.

Perhaps more important than the final verdict on ORBES is the learning process it stimulated. Reports, even the best of them, gather dust, but ideas exchanged in the classroom and the marketplace stay alive. If a new learning and teaching process, centered on the problems of the Ohio River Basin, has begun, the ORBES experiment will have been worthwhile.

One important insight gained by the researchers is that the ORBES region, part of which is known popularly as the Ohio River valley, is far more diverse than they had suspected and probably more so than most public officials realize. Failure to recognize this diversity most certainly will doom to failure any attempt at basinwide institutional innovations. For example, the organization responsible in part for the study--Save the Valley, which is centered around Madison, Indiana, between Cincinnati and Louisville--includes individuals who fear that power plants and related installations will transform the area into one of heavy industry. Their spokesmen often extoll the natural beauty and rural advantages of their section of the valley. They speak of a desire to keep it from becoming "another Gary, Indiana, or a Youngstown, Ohio," filled with factories and dirty air.

It is indeed ironic that most members of a movement known as Save Our Valley are residents of Youngstown. The major objective of these citizens is to "save" jobs from being lost by the closing of steel mills in the area. Church leaders and others argue for the development of more industry. In efforts to save jobs and to maintain a desirable quality of life from their perspective, at times they have contended that air quality standards must be relaxed. Equally committed individuals in Save The Valley call for the imposition of stricter air quality standards.

The diversity of the ORBES region and the complexity of its economic and environmental problems are well illustrated by the presence of organizations such as Save The Valley and Save Our Valley. They function in adjacent states but are separated in their views on what is in the best interest of their communities and of the broad region. There is indeed balkanization within the ORBES region, and with a continued emphasis on coal, ideological divisions probably will become more pronounced.

The single issue within the broad context of continued (and perhaps increased) reliance on coal that could produce the most conflict is the long-range and transboundary movement of air pollutants across state lines. Since ORBES began in 1976, this issue has become perhaps the most prominent one in the region. It affects employment levels in the coal-mining industry as well as in industry in general. It triggers emotions that are easily translated into political controversy. Some feel that such political controversy, both intrastate and interstate, could threaten the stability of the American federal system.

But many of the ORBES researchers--air pollution experts, economists, lawyers, political scientists, and others--believe that institutional mechanisms can be devised that will permit the region to enjoy the benefits of both reasonably clean air and a degree of economic growth. The creation of such mechanisms will require the highest technological competance, as well as social and political imagination. If there is any single finding of the Ohio River Basin Energy Study, it is that steps toward both clean air and economic growth in the region can be taken only if ways can be found to unite the various factions. Many residents of the region have recognized this reality, but they remain separated by ideology. Some believe that the steps should be initiated by government, while others favor action within the private sector. It is not the responsibility of ORBES researchers to recommend which path should be followed. But it is our responsibility to warn that inaction could result in economic stagnation and accompanying social problems capable of draining much-needed vitality from the region and from the nation at-large.

Appendices

APPENDIX A

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APPENDIX B

ORBES Publications

Phase II

Donald A. Blome, University of Kentucky, *Coal Mine Siting for the Ohio River Basin Energy Study*, Grant No. EPA R805590

E. Downey Brill, Jr., Shoou-Yuh Chang, Robert W. Fuessle, and Randolph M. Lyon, University of Illinois at Urbana-Champaign, *Potential Water Quantity and Water Quality Impacts of Power Development Scenarios on Major Rivers in the Ohio Basin*, Subcontract under Prime Contract EPA R805588

Vincent P. Cardi, West Virginia University, editor, *West Virginia Baseline*, Grant No. EPA R805585

Vincent P. Cardi, Larry Harless, and Thomas Sweet, West Virginia University, *Legal and Institutional Issues in the Ohio River Basin Energy Study*, Grant No. EPA R805585 and Subcontract under Prime Contract EPA R805588

Duane Chapman, Kathleen Cole, and Michael Slott, Cornell University, *Energy Production and Residential Heating: Taxation, Subsidies, and Comparative Costs*, Subcontract under Prime Contract EPA R805588

Comments on the Ohio River Basin Energy Study, Cooperative Agreement No. EPA CR807395

Control Data Corporation, International Research and Technology Corporation, and the MITRE Corporation, *Environmental Residual Trends in the Ohio River Basin*

Gary L. Fowler, University of Illinois at Chicago Circle; J.C. Randolph, Indiana University; Robert E. Bailey, The Ohio State University; Steven I. Gordon, The Ohio State University; Steven D. Jansen, University of Illinois at Chicago Circle; and W.W. Jones, Indiana University, *The Ohio River Basin Energy Facility Siting Model*, Grant Nos. EPA R805588, R805589, and R805609 and Subcontract under Prime Contract EPA R805588

Vol. I. *Methodology*

Vol. II. *Sites and On-Line Dates*

Steven I. Gordon and Christopher Badger, The Ohio State University, *A Model of Migration in the Ohio River Basin Energy Study Region*, Subcontract under Prime Contract EPA R805588

Steven I. Gordon and Anna S. Graham, The Ohio State University, *Regional Socioeconomic Impacts of Alternative Energy Scenarios for the Ohio River Basin Energy Study Region*, Grant No. EPA R805589

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Steven D. Jansen, James P. Hartnett, R. Mastaniah, and Dan Merilatt, University of Illinois at Chicago Circle; Robert E. Bailey, The Ohio State University; J.C. Randolph, Indiana University; Maurice A. Shapiro, University of Pittsburgh; and Hugh T. Spencer, University of Louisville, *Nuclear Energy Risks and Benefits*, Grant Nos. EPA R804816, R805588, R805608, and R805609 and Subcontracts under Prime Contract EPA R805588

Boyd R. Keenan, University of Illinois at Chicago Circle, *Ohio Basin Interstate Energy Options: Constraints of Federalism*, Grant No. EPA R805588

Clara Leuthart and Hugh T. Spencer, University of Louisville, *Fish Resources and Aquatic Habitat Impact Assessment Methodology for the Ohio River Basin Energy Study Region*, Grant No. EPA R804816

Orie Loucks, Thomas V. Armentano, Roland Usher, and Wayne Williams, The Institute of Ecology; Richard W. Miller, The Institute of Ecology and Butler University; and Larry Wong, Indiana University, *Crop and Forest Losses Due to Current and Projected Emissions from Coal-Fired Power Plants in the Ohio River Basin*, Subcontract under Prime Contract EPA R805588

Patrick C. Mann and Tom S. Witt, West Virginia University, *An Economic Analysis of the Electric Utility Sector in the Ohio River Basin Region*, Subcontract under Prime Contract EPA R805588

James A. McLaughlin, West Virginia University, *Legal and Institutional Aspects of Interstate Power Plant Development in the Ohio River Basin Energy Study Region*, Subcontract under Prime Contract EPA R805588

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Walter P. Page, West Virginia University, *Energy Consumption in the Ohio River Basin Energy Study Region, 1974, by End User and Fuel Type*, Grant No. EPA R805585

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Jan L. Saper and James P. Hartnett, University of Illinois at Chicago Circle, editors; Vincent P. Cardi and Thomas Sweet, West Virginia University; and Gary L. Fowler, Rita Harmata, Steven D. Jansen, and Boyd R. Keenan, University of Illinois at Chicago Circle, *The Current Status of the Electric Utility Industry in the Ohio River Basin Energy Study States*, Grant Nos. EPA R805585 and R805588

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James J. Stukel, University of Illinois at Urbana-Champaign, editor, *Ohio River Basin Energy Study: Air Quality and Related Impacts*

Vol. I. James J. Stukel and Brand L. Niemann, University of Illinois at Urbana-Champaign, *Documentation in Support of Key ORBES Air Quality Findings*, Grant No. EPA R805588

Vol. II. Teknekron Research, Inc., *Air Quality and Meteorology in the Ohio River Basin: Baseline and Future Impacts*, Subcontract under Prime Contract EPA R805588

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NOTE: Copies of the above reports can be obtained from Office of Research and Development Publications, U.S. Environmental Protection Agency, Center for Environmental Research Information, 26 West St. Clair, Cincinnati, Ohio 45268 (513/684-7562).

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Donald A. Blome and James E. Jones, Jr., University of Kentucky, *Regional Assessment of the Impact of Synthetic Fuel Production*, vol. III-J, Grant No. EPA R804817

E. Downey Brill, Jr., Glenn E. Stout, Robert W. Fuessle, Randolph M. Lyon, and Keith E. Wojnarowski, University of Illinois at Urbana-Champaign, *Issues Related to Water Allocation in the Lower Ohio River Basin*, vol. III-G, Grant No. EPA R804821

Robert C. Dauffenbach and Thomas P. Milke, University of Illinois at Urbana-Champaign, *Labor Demand Impact and Labor Market Feasibility of Energy Conversion Facilities in the Ohio River Basin*, vol. III-A, Grant No. EPA R804821

Development of Baseline Data for the Ohio River Basin Energy Study, vol. I-B, University of Louisville, University of Kentucky, University of Illinois at Chicago Circle and at Urbana-Champaign, Indiana University, Purdue University, The Ohio State University, and Project Management, Grant Nos. EPA R804816, R804817, R804821, R804849, R804851, and R804848

Independent Comments, vol. IV, Grant No. EPA R804848

Sue Johnson and Esther Weil, University of Kentucky, *Social Aspects of Power Plant Siting*, vol. III-D, Grant No. EPA R80817

Clara A. Leuthart and Hugh T. Spencer, University of Louisville, *Radionuclide and Metal Ion Content of Late Summer Ohio River Sediments: McAlpine Pool 1976*, vol. III-I, Grant No. EPA R804816

Sven B. Lundstedt, Henry L. Hunker, and Clark Leavitt, The Ohio State University, *Subjective Quality of Life in the Ohio River Basin as Related to Future Energy Development*, vol. III-C, Grant No. EPA R804851

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Preliminary Technology Assessment Report, Vol. II-C, University of Illinois at Chicago Circle and at Urbana-Champaign, Grant No. EPA R804821

Michael Rieber, University of Illinois at Urbana-Champaign, *Energy Transportation/Distribution in the Ohio River Basin*, vol. III-F, Grant No. EPA R804821

Richard A. Tybout, The Ohio State University, *A Benefit-Cost Analysis of Power in the ORBES Region*, vol. III-B, Grant No. EPA R804851

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Findings, vol. I-A, Grant No. EPA R805848; also published as U.S. Environmental Protection Agency, Interagency Energy-Environmental Research and Development Program Report, EPA-600/7-77-120 (November 1977)

Nicholas L. White and John F. Fitzgerald, Indiana University, *Legal Analysis of Institutional Accountability for the Ohio River Basin*, vol. III-E, Grant No. EPA R804849

APPENDIX C

Alternative Scenario Designations

	Number	Other Designation
Scenarios Discussed in Main Report		
Base Case (BC)	2	Business as Usual (BAU)
Strict Environmental Controls (SEC)	1	
SIP Noncompliance (SIP–N)	2d	Lax Environmental Controls
High Electrical Energy Growth (HEG)	7	
Electrical Exports (EX)	2a	Coal-fired Exports; "Wheeling"
Natural Gas Substitution (NG)	4	
Nuclear Fuel Substitution (NF)	2c	
Alternative Fuel Substitution (AF)	3	
Conservation Emphasis (CON)	6	Very Low Energy Growth
Scenario Variations Discussed in Main Report		
Agricultural Land Protection, Dispersed Siting	1c	
Agricultural Land Protection, Concentrated Siting	1d	
Once-through Cooling	2i	
High Electrical Energy Growth, Least Emissions Dispatch	7a	
High Electrical Energy Growth, 35-year Plant Life	7b	
Specialized Scenarios Discussed in Other ORBES Reports		
Very Strict Air Quality, Dispersed Siting	1a	
Very Strict Air Quality, Concentrated Siting	1b	
Electrical Exports, Dispersed Siting in Western ORBES Region	2a1	
Electrical Exports, Nuclear-Fueled	2b	"Wheeling"
Electrical Exports, Nuclear-Fueled, Once-through Cooling on Ohio Main Stem	2b1	"Wheeling"
Low Economic Growth	5	
Very High Economic Growth	5a	

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